Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 223 MAY, 1937 No. 5

TIME DETERMINATION AND TIME BROADCAST.*

BY

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As far back as history, and even legend, carry us, man has tried continuously to devise methods of determining and of

* Presented at a meeting held Thursday, October 29, 1936.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

keeping time. The earliest attempts were very crude and naturally divided themselves into two general groups: (1) those in which the positions of the stars and the sun were observed with reference to objects near at hand; and (2) those in which efforts were made to measure the elapsed time.

In the first class, whatever their form, all were some type of sundial or some crude form of a transit instrument. The first attempts were satisfied by a range between two widely separated objects that happened to lie in the meridian.

In the second class, the earliest efforts consisted in the burning of rope knotted at regular spaces, or the draining of water or sand from one container to another; or, as was reputed to have been done in early China, the burning of candles. Each effort was an attempt to improve on the best previous method.

All modern methods of time determination are based on the uniform rotation of the earth on its axis. The interval between two successive transits of the same star over the same meridian measures one complete revolution of the earth. That constitutes a sidereal day. It is conveniently divided into 24 hours and each hour is further divided into minutes and seconds.

The earth is our best master clock. It requires neither winding, resetting, oiling, nor repairing to make it keep accurate time. If by some trick of magic we could secure marks in the sky, indicating the hours, minutes and seconds, we could all throw away our watches and clocks. Inasmuch as that is impossible, we naturally turn to the stars which are our nearest approach to hour marks in the heavens. They are so distant that we can use them with the greatest accuracy in measuring the period of the earth's rotation. As a matter of fact, if you know your stars, you can very closely approximate the hour marks in the heavens. Observing the stars as they apparently swing across the heavens, and noting the exact instant of the meridian passage by some clock, permits us to determine the error of that clock with great exactness.

The continuous effort for years to develop clocks, each expected to maintain time more accurately than all previous ones, parallels the history of man and measures his progress. For years, the most accurate clocks have been made abroad,

England, France and Germany vying with each other to produce the most accurate timepiece in the world. And now we come to the latest development—the crystal oscillator—which at one stroke cuts loose from all the troubles inherent in pendulum clocks. True it has faults of its own, but they will be overcome.

Returning to the stars, if you will memorize the right ascensions of some of the most prominent stars in the principal constellations, you will have established a celestial clock capable of use every clear night.

EARLY EFFORTS IN MECHANICAL BROADCASTING OF TIME PRIOR TO RADIO.

Prior to 1830, there was no satisfactory method of fulfilling the Navy's requirements. These requirements included charts, navigational instruments, chronometers, nautical information, etc. Whenever a ship was placed in commission, commercial agents abroad purchased the required instruments, charts, books, etc. As these commercial agents usually knew little about navigation, their inspection was more or less superficial, and when the equipment was received in the United States, it very frequently was found unsuited for the purpose. In addition, charts, books, pamphlets, etc., were in foreign languages and had to be translated; and, also, charts were not constructed with a common zero meridian so they all had to be redetermined to obtain a uniform system for safe navigation.

When a ship was decommissioned, all of her equipment was stored in a storehouse in some navy yard. Little attention was paid to it and the result was inevitable. When the equipment was again needed, it was usually found unfit for use and the Navy had to repurchase, through the same commercial agents, new equipment which repeated the same defects.

A young naval officer, Lieutenant Goldsborough, recommended to the Department the establishment of a Depot of Charts and Instruments; and, in 1830, the Secretary of the Navy ordered Lieutenant Goldsborough to establish this Depot and take charge of it. One of his most important duties was the determination of accurate time and the dissemination of that time to ships of the Navy. In the beginning, there

was no way of doing that except by actually carrying a chronometer, accurately rated, to the port in which ships were lying, where the chronometers on the ships could be compared and accurate rates established.

Until a comparatively recent date, ships on isolated stations had to determine their chronometer errors by celestial observations. If the ship happened to be in an American port, it obtained its error by "tick" through the Western Union Telegraph Company; but frequently, even as late as the beginning of the present century, the young assistant navigator had to take his artificial horizon ashore and make observations for chronometer error.

Until 1864, and in many places subsequent to that date, the only method of broadcasting time was by dropping a time ball from some conspicuous building visible to the surrounding country and harbor.

In 1864, the city of Washington established one of the first electrical central fire alarm systems. The Mayor of Washington—in those days Washington had a Mayor—was very proud of this system. The Superintendent of the Naval Observatory seized the opportunity to use the fire bells as a means of broadcasting accurate time. On his recommendation, a private wire was run from the Naval Observatory to the Central Fire Station and at 7 o'clock every morning and 6 o'clock every night, either the Superintendent himself or Dr. Harkness pushed the button which rang the fire bells all over the city. The State Department, which at that time occupied an old building on 14th Street, requested that, when the signals were transmitted to the Central Fire Station, they be also transmitted to the State Department, because of its importance to them.

The Western Union Company had established an office in the building for the convenience of the State Department, and it happened that their operator was a very wide awake young man. Appreciating the value of time to his Company, every time the signal from the Naval Observatory came over the wire to the State Department, he repeated it to the Western Union Telegraph's Central Office. The Western Union Telegraph Company immediately appreciated the financial value of this accurate time service and they began trans-

mitting time by wire to all cities. They advertised extensively the advantages of their time service. This is the origin of the Western Union Telegraph Company's time service.

In the early days, the Railroad Companies all determined their own time and operated their trains on their own schedules. Lines that ran across the continent had to change their time from point to point in order to approximate the local time. But it was seldom that the times agreed. For instance, in a Pittsburgh station there were three clocks, one showing Philadelphia time, one showing time much further west, and one showing Pittsburgh time. The passengers frequently missed their trains because of the resulting confusion.

In 1883, the railroads of this country in convention adopted the idea of a standard time. This was one of the most important steps in the standardization of time ever taken by any group of men. On the 18th of November, 1883, fifty different standards of time in the United States were resolved into four. The United States was divided into four zones, each zone based on the well known astronomical fact that the earth revolves through 15° per hour, or through 360° per day of 24 hours mean time. This revolutionary action aroused violent discussion. It was considered a violation of the acts of God, and it was predicted that this sacrilege would certainly result in dire disaster. It was even prophesied that divine manifestations would surely follow.

Upon the recommendation and invitation of the United States, an International Convention met in Washington in 1884 and established a standard time for the world and a standard marking of longitude. The meridian of Greenwich was established as the zero meridian of the world, from which all other meridians were measured.

In the early days, many municipalities wanted to buy time. A number of observatories determined time and sold it in their own localities. Finally, resentment against Western Union's monopoly on the dissemination of Naval Observatory time culminated in a congressional investigation which was sponsored by 23 observatories in the United States. It was stated that the Western Union Company charged those observatories so much for the transmission of time to their patrons that the observatories could not afford to sell time

any longer. Therefore the Western Union had developed a monopoly.

Thanks to the logical reasoning of the Superintendent of the Naval Observatory, who premised his argument on the greatest good to the greatest number, it was shown to the satisfaction of the Congressional Committee how the arrangement between the Naval Observatory and the Western Union had started, how it had developed to the benefit of the whole country, and why it would serve no purpose, and do no good to stop the furnishing of time to the Western Union by the Naval Observatory.

One of the most progressive cities in this country, Leavenworth, offered to buy time once a month. It was to be transmitted to the principal jeweler in that city and by him was to be furnished to everybody in the city of Leavenworth.

Soon, time was telegraphed to many cities and to all seaports and time balls were dropped from a conspicuous building in each port.

In addition, arrangements were made so that any ship captain could visit any Western Union Telegraph office and receive the noon signal free of charge.

But it is to the scientists of the world that credit is due for the constant increase in the accuracy of time. Scientists always work with fundamental units, such as units of length, weight, and time. The units of length and weight are tangible, but the unit of time is not and yet time enters into practically all calculations.

Prior to 1904, the only means of transmitting time was by the Telegraph Companies. This introduced a lag due to the transmission of the signal over land wires. Naturally, this variable could not be known with great accuracy.

In September 1903, the Navy began building its first radio broadcasting station at Navesink, N. J. Throughout the winter they worked, and in the spring of 1904, the first broadcast of correct time by radio signal was inaugurated. Of course those early time broadcasts were not very powerful, but they stimulated all hands to greater effort. In those days, the present high power radio stations were only dreams; but the news of our little low powered radio broadcast from Navesink was heard around the world.

From that time on, anyone, whether at sea or on shore, could intercept our time signals and receive them with the greatest accuracy then known, if they were equipped with receiving apparatus capable of picking up our signals.

The Navy's next contribution to science was the completion of the Arlington High Power Radio Broadcasting Station. In December, 1912, the Navy completed its big station and immediately began broadcasting accurate time on high power.

The Superintendent of the Naval Observatory again saw an opportunity to advance scientific progress. He recommended that an effort be made to determine the difference in longitude between Europe and the United States by means of radio. In 1913 and 1914, this was successfully accomplished, the Naval Radio Station at Arlington and the Eiffel Tower in Paris being used for the communication. These observations were the first direct determination of the difference of longitude and the velocity of transmission of radio waves between the United States and Europe. Years before, in 1846 and 1847, the Naval Observatory pioneered in the determination of differences of longitude by means of telegraph, first using Baltimore and Washington and later using Havana and various cities in the United States.

It should be a matter of interest and pride to Americans that the Navy's first low powered time broadcast in 1904 antedated the British first broadcast via the British Broadcasting Company by approximately nineteen years. Records show their first broadcast was made on 5 February, 1923.

The Navy's first high power time broadcast in December, 1912, likewise antedated Rugby's first effort on 19 December, 1927, by many years.

In 1930, the Naval Observatory was broadcasting time three times daily with an accuracy of a couple of hundredths of a second. At the National Academy of Science's annual convention, in April of 1931, the requirements of the scientists were emphasized very strongly. They required more frequent and more accurate signals. The contrast between present day demands and those years ago when the city of Leavenworth wanted to buy time once a month, and pay for it, is very interesting.

We immediately jumped our program to six daily broadcasts. More would have been made but we were at the limit of our capabilities. We could not obtain additional funds to engage additional astronomers to handle the increased load on the time service. And without additional astronomers we could not undertake more broadcasts.

As always occurs when circumstances become compulsory, the good Lord provides. One night while working in my office near midnight, a solution flashed through my mind with such clearness, it was startling.

The next morning, the scheme was explained to the Navy Department and a small amount of money was obtained to commence construction. Progress was necessarily slow as funds were limited, and much of the work had to be done by our own force in addition to our regular work. It is therefore not surprising that the apparatus was not completed until May of 1934.

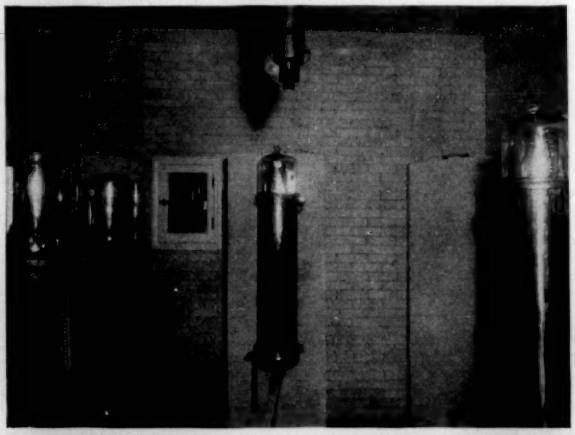
After an exhaustive unofficial test of about five months with the apparatus running continuously twenty four hours a day, we began our official program of 20 broadcasts daily. I would have preferred twenty-four broadcasts daily, but the other equally important federal broadcasts prevented my obtaining the necessary time at nine and eleven A.M. or nine and eleven P.M. Since September 7, 1934, the Naval Observatory has been broadcasting accurate time twenty times daily, with reduced labor and increased accuracy.

DETERMINATION OF TIME.

All observatories in the world have always determined time by observing visually the transit of the stars over their meridians. This method is subject to errors due to the possible flexures of the telescope and also the personal equations of the various astronomers. Due to the rotation of astronomers in observing the transits of time stars, another variable is introduced. Not being satisfied with this system, the Naval Observatory pioneered in an entirely different direction.

We have an instrument which has been used in the past for the determination of the variation of latitude. It is known as the Photographic Zenith Tube. One of the members of the staff, Mr. Willis, conceived the idea; and the P. Z. T. was

modified to cover the new task. This instrument consists of a fixed vertical tube with a mercury basin at the lower end. Its objective and the carriage for the photographic plate are at its upper end. The light from a star passing near the zenith of the Naval Observatory passes through the objective, is reflected from the surface of the mercury, and comes to a focus on the under surface of a photographic plate mounted just under the objective. Due to the design of the objective,



Time Vault. Placed in commission in March 1933, it has maintained constant temperature and pressure within minute limits. The Synchronome Co., Ltd., sent a representative to inspect our installation. His opinion expressed immediately after inspection was that the vault itself was a large factor in the very excellent performance of their "Shortt" clocks.

Both Shortt and Reiffler clocks are seen in the picture, also the bottom of the periscope let down through the roof, and the magazine lights up near the roof on back and right walls.

its optical center is located below it in the plane of the photographic plate just mentioned.

This photographic plate is supported in a carriage driven back and forth along a track in either the East-West, or the West-East direction. This track is rigidly attached to the cell of the objective. The driving power for the movement of this plate carrier is furnished by a 1,000 cycle synchronous motor driven from the output of the piezo-electric crystal

controlled oscillator. This same oscillator provides the power for driving the time signal transmitting apparatus. Because of this, the driving speed of the plate carrier is extremely uniform. The plate moves along the track at exactly the same speed that the earth's motion causes the star image to move.

The clear aperture of the objective is about 8″, its focal length is 203″, and the photographic plates are 1¾″ square.

Navy Day visitors operating the old submarine's periscope which permits them to see all the precision time pieces "clocks" which keep the Nation's time.
They are housed in the double vault below where temperature and air pressure are maintained constant.
The periscope aside from permitting the visitors to satisfy their desire to see the clocks also permits daily visual inspections of all.

Four exposures are made for each star. If the plate did not move these exposures would appear as line trails, but as the plate does move at the same speed as the stars apparently move, the photograph shows small sharp points. Alternate exposures are made with the plate in one position, the other two with the plate revolving through 180°.

From these four images the time of transit is determined.

On every clear night, 18 or more stars are observed. By comparing the known times of meridian transits of the stars with their photographed times of transit, errors of the Observatory clocks are determined.

It is interesting to note that comparisons of the results obtained, extending over a long period, with this zenith tube and those obtained by visual transit instrument show a marked superiority in the photographic method. But this is to be expected inasmuch as the personal equation of the observers and the effect of tube flexures are entirely eliminated.

BROADCASTING OF TIME.

Prior to 1934, time signals were broadcast by the astronomer on watch who had to perform the various steps in checking the accuracy of the clock prior to each broadcast. This procedure included a comparison between the transmitting clock, maintaining mean time, and the standard clocks in the vault, maintaining sidereal time, by means of a chronograph. After the chronograph run was completed, the error of the mean time clock was calculated, and by reference to our established tables, the length of time necessary to apply an electrical influence through a solenoid at the center of the pendulum swing was determined. After the application of this electrical current during a pre-determined time, either to retard or to accelerate the swing of the pendulum, a second chronograph run was then made to determine how accurately the error of the clock on mean time had been absorbed. If the correction had been accurately made, the clock was then ready for broadcast. This operation required about 16 minutes for an expert astronomer. With our limited personnel, we therefore could not make more than six broadcasts a day.

The recently invented automatic broadcaster immediately changed this entire procedure.

AUTOMATIC TIME BROADCASTER.

The automatic time broadcaster has a triple personality. (1) it is a crystal controlled clock; (2) it is its own chronograph; and (3) it is an automatic time broadcaster.

The crystal controlled oscillator was made for us by the General Radio Company. The quartz crystal has a fre-

quency of 30,000 cycles per second. This quartz crystal is inclosed in a double temperature controlled compartment. The 30,000 cycle output is fed directly into two sub-multiple generators. One of these generates a frequency of 6,000 cycles. The other one generates 5,000 cycles. These two

Automatic Time Service Apparatus.

At the extreme left: Crystal oscillator. In the left center: Special switchboard designed so as to permit comparisons universally either by means of a chronograph or by means of the new apparatus. Right center: The printing chronograph which prints the record of all signals received over the air and through our system from the vault and broadcasting units. Extreme right: The New Automatic Time Service Broadcasting unit.

This apparatus contains within itself its own self controlled crystal clock; an apparatus that serves the purpose of a chronograph for comparison purposes, and an automatic broadcasting unit which broadcasts the time signal twenty times daily, automatically. This apparatus is capable of dividing one second of time into 1,000 parts, and the measure of each part can be seen visually through the small telescope on the right edge.

are combined and fed into a detector and amplifier unit. The amplifier unit takes the difference of the two frequencies; that is, 1,000 cycles, and amplifies it to the full output of three standard type No. 41 tubes.

The resulting magnified power is then used to operate a synchronous motor. The field coils of the motor can be

rotated. This permits the application of corrections to the device without interference with its operation. If the field coils are rotated through three hundredths of a revolution, a correction of exactly three one-thousandths of a second of time will have been applied.

The shaft of this synchronous motor is geared to a vertical shaft which is made to rotate at exactly one revolution per second. Mounted securely on this vertical shaft is a glass disc whose periphery is etched with 1,000 divisions. Inasmuch as the shaft and the glass disc revolve exactly one revolution a second, each of the divisions on the periphery of the glass disc therefore measures one one-thousandth of a second. Below this glass disc, in the lower compartment, is carried the master cam which produces the time signal beats.

From this description, you see that every time the neon light is made to flash by the standard clock in the vault, the etched marks on the revolving disc can be observed with great clearness. The shortness of the neon flashes causes the optical delusion that the rotating dial is stationary and makes it possible to read the time of the flash to the one one-thousandth of a second. In this way by connecting the neon light with any timepiece, a very quick and accurate comparison can be made with the transmitting device.

The procedure is as follows:

The astronomer slips the key through the hole in the side of the case abreast of the field coils of the synchronous motor. He observes the flash of the neon light, and turns the field coils either to the right or left until he observes by the flashes of the neon light that the error has been absorbed and the transmitter is exactly on time. He then withdraws the key, throws off the switch, and goes about his other duties.

Every hour during the day and night, except 9 and 11 A.M., and 9 and 11 P.M., this automatic apparatus throws its own switch which flashes a signal at Arlington. The radio man on watch throws his switch which places the automatic broadcaster in control of the broadcast through distant control. At exactly five minutes of the hour, the automatic broadcaster begins and transmits the signal with the accuracy of one one-thousandth of a second.

After the signal is on the air, and in order that we can determine any errors in the actual emission of the time broadcast, we receive over our own antenna the broadcast. Our receiving sets in the time service office, also made by naval personnel, then convert the signals into mechanical energy and operate a printing chronograph, which was invented by Mr. Sollenberger some years ago. This gives us a permanent record of every signal from this Observatory. We can also receive and record signals from other sources.

One of the many advantages of this new automatic broadcaster is that by installing duplicate sets at distant points we can accurately rebroadcast our signals from those points. When the apparatus is installed at distant points, the neon light is flashed by the reception of the time signal by radio instead of by the beat of the standard clock in our vault. The operator at the distant points then corrects the broadcaster in the same manner we do here, using the radio broadcast signal received. When he has his broadcaster in step with the radio time signal received and has absorbed the lag due to the time of radio transmission, his apparatus is ready for rebroadcast, and he likewise goes about his other duties. At five minutes of the hour, at the times designated for his station, his apparatus rebroadcasts the Washington signal with the same accuracy.

In contrast with the 16 minutes consumed in preparation for broadcast under the old method, the automatic method can be set within five or ten seconds. As a result, with no increase in our astronomical staff, we are now able to broadcast signals once an hour. As soon as the new sets are completed and installed at Panama and at Honolulu, we will be able to reach naval vessels and American merchantmen any place in the world.

Our original automatic broadcaster was placed in service in May 1934, and has been used continuously ever since. We are now building a new set, approximately the same in general design, but differing in some mechanical details, in order to reduce wear of parts, insure greater durability, and reduce risk of interruption. The fundamental principles involved are identical.

In closing I wish to pay just tribute to the unfailing energy and loyal coöperation of all the personnel at this institution who so ably assisted in perfecting and machining all the parts for this rather complicated apparatus. In particular, I wish to emphasize the wholehearted coöperation of Mr. Paul Sollenberger in the completion of this broadcaster.

During the International Astronomical Union's Convention in Paris, in July, 1935, the Naval Observatory's automatic broadcaster occasioned considerable comment by the assembled delegates. Three representatives from foreign countries have already visited this institution and observed its operation.

Electrical Water-Level Control and Recording Equipment for Model of Cape Cod Canal.—H. L. HAZEN (*Electrical Engineering*, Vol. 56, No. 2). A very unusual condition with regard to tides is that existing at the Cape Cod Canal, eight miles long, extending from Cape Cod Bay to Buzzards Bay. In this canal relatively high velocities of flow occur caused by the fact that the tidal range in Cape Cod Bay is somewhat more than twice that in Buzzards Bay and high water occurs in Buzzards Bay about three hours before it occurs in Cape Cod Bay. A hydraulic model was constructed in order to study the flow, and the effect of enlarging the canal. In order to reproduce tidal water level variations, automatic water level control equipment was necessary together with accurate water level records. In-as-much as the model was small (scale 1 to 600) the use of floats was unsatisfactory. The water level control is accomplished with two simultaneous adjustments. The first, or coarse adjustment, is obtained by a time controlled flow of water into the deep water end of each basin at either end of the canal and the second or accurate water level adjustment is by automatically controlling the height of a discharge weir at the end of each basin. To do this with the required accuracy the design was based on an analysis of the dynamics of the system. A master time unit was used which consisted of an adjustable speed d.-c. motor geared to a Selsyn system of motors which drove cams revolving synchronously at a speed equal to one revolution per tidal cycle. This period in nature of 12.42 hours was reduced to 9.63 minutes in the model. The water level was made to conform with the tidal data given on the cams. For the water level recording equipment, the water surface is used as one electrode of an electrostatic potential divider from which the grid potential of a pentode is derived. The d.-c. component, of plate current, is used to indicate the level, indicated by a d.-c. milliameter. The simultaneous recording of the indications for the nine water level stations in the model is done photographically.

R. H. O.

THE STORY OF THE FRANKLIN INSTITUTE.

BY

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II. A CENTURY OF SERVICE.

Following the auspicious beginning of The Franklin Institute and the intense activity of the first few years, came a long period of service and development. The reputation of the Institute increased in this country and abroad and its advice was frequently sought on questions of technology and education. Sister organizations were founded in other cities with which friendly relations were soon established to their mutual advantage.

GOVERNMENTAL SERVICE.

Many activities were carried on by the Institute that are now, to a greater or less extent, functions of the Government. In some cases the Institute initiated a new service which was later adopted by the Government. In others it supplemented or assisted a service that was already a part of the Governmental program, but could be rendered more effectively by such coöperation. In every instance, when the time came that the services of the Institute were no longer needed, it quietly withdrew and interested itself in some new field of endeavor.

The Federal Government.

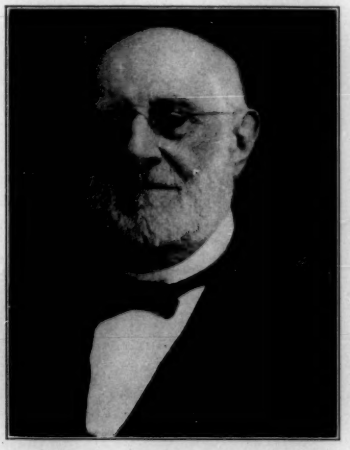
Reference was made in the preceding chapter to the study of the strength of materials used in the construction of steam boilers. This work was aided by a grant from Congress, but was initiated and carried to completion by the Institute. Such work is now a part of the service rendered to industry by the National Bureau of Standards, which was established in 1901 under the administration of President McKinley.

Monthly weather reports were published in the JOURNAL starting in January 1831 and continuing through December

THE MEMBERSHIP CERTIFICATE.

This certificate, engraved by John Sartain, is still in use for certain classes of members. The illustration is reduced from 21″ × 26″.

1843. These included the phases of the moon and, for each day of the month, the temperature, barometer and wind at sunrise and at 2 P.M., rainfall, and remarks. Under the latter heading besides the commonplace "clear," "cloudy" or "rain," were more intimate touches such as "good sleighing," "nav obstr'd," "Delaware frozen." A summary for the month followed. It is noted that about this time lectures on meteorology were given by Dr. Gouverneur Emerson to the students in the High School. He and Mr. James P. Espy played a conspicuous part in these early studies of the weather and were frequent contributors to the JOURNAL.



FREDERICK FRALEY, 1804–1901.

One of the founders of the Institute and for thirty-six years its Treasurer, a Trustee of Girard College and President of the American Philosophical Society for 22 years. He was Treasurer of the School of Design of the Institute.

Three years later, in coöperation with the American Philosophical Society, observations were made in every county of the state. The Legislature appropriated funds for the purchase of equipment and genuine advances were made in the science of meteorology. The support of the Philosophical Society was shortly withdrawn, that of the State a few years

later, and although the aid of Congress was asked, the government was not yet ready to lend its support to these studies. These weather observations were among the first that were made primarily as an aid to agriculture. A weather map, taken from the JOURNAL, indicates how the movement of storms across the country was studied and recorded in 1838.

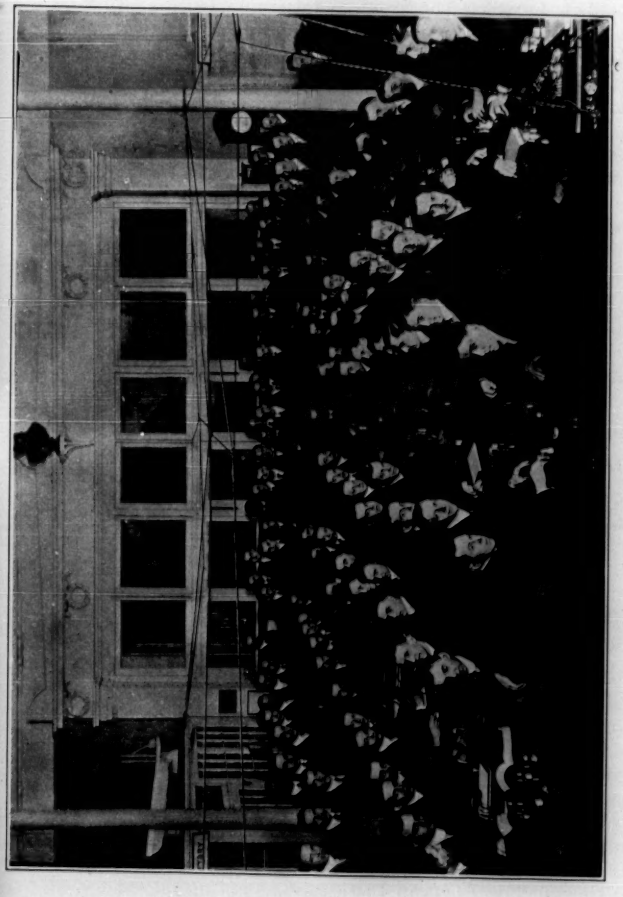
Not until 1887 were systematic weather observations continued throughout the state, when a State Weather Service was inaugurated by The Franklin Institute with the support of the Legislature and the assistance of the Signal Corps of the United States Army which had undertaken that service in 1870. Its affairs were directed from the Institute with a staff of voluntary observers through the state. The service was continued until 1891 when the state discontinued the small appropriation which paid for necessary clerical work.

Prior to 1868 there was no uniform plan for the design of screw threads, bolt heads and nuts. As a result a great variety of these articles were manufactured, and it was virtually impossible to fit any two together unless they were of the same design. In 1864 William Sellers, President of The Franklin Institute, suggested at one of the meetings that a uniform system should be established. A special committee investigated the question and decided upon a system to recommend. This was adopted by the United States Government in 1865 and has proved of great service. It has been known as the Sellers or Franklin Institute System. Nowadays, if a nut is lost in a Mexican town from an automobile manufactured in Detroit, it is possible to replace it in the local hardware store.

A more recent service to the Federal Government was rendered during the World War when the Institute met the emergency in a three fold manner. It established a recruiting and examination station for applicants for admission to the Aviation Service of the United States Army. It established a School of Navigation for the United States Shipping Board, and it conducted a free Radio School for men of the selective draft.

The Commonwealth.

Besides the establishment of a State Weather Service as above related, there were two other notable activities on the

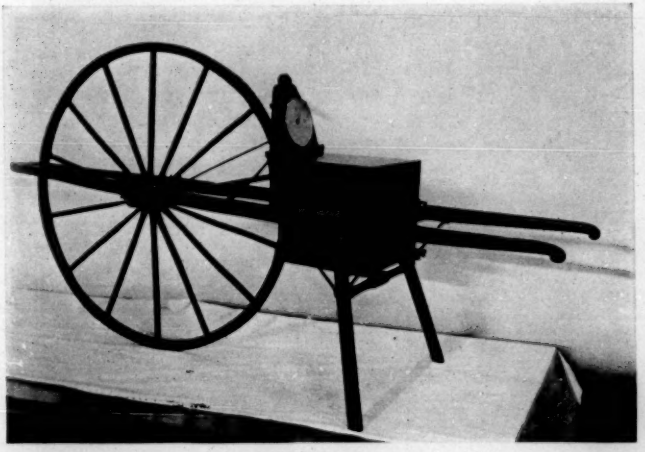


THE RADIO SCHOOL, 1917–18.

The Reading Room was used for this purpose during the World War.

part of the Commonwealth of Pennsylvania during the last century, in which The Franklin Institute participated.

A bill was proposed in the Legislature in 1833 relating to weights and measures, and the Institute was requested to examine and report upon it. The report, prepared by a committee of the Institute, was published in the JOURNAL over a period of several months and included a detailed statement on the weights and measures of France, England, and the United States, as well as an authentication of the Troy



LESLEY'S ODOMETER.

This machine for measuring distance was used in connection with the Second Geological Survey of Pennsylvania.

pound used in the United States Mint. The standards were constructed under the supervision of the Committee and the present laws of the state are based on its recommendations.

The First Geological Survey of Pennsylvania had been made over a period of years commencing in 1834. A number of members of the Institute had participated in the work. Although The Franklin Institute had no official connection with this survey, there is reason to suppose that an investiga-

tion into the resources of the Commonwealth commenced by the Institute two years earlier, may have exerted some influence in its favor. In 1873, however, on the suggestion of the Governor, Professor J. B. Lesley, a member of the Institute, wrote to him at length calling his attention to the desirability of another survey. The letter, which was published in the JOURNAL, submitted suggestions for a complete working corps for the operations of the various departments of the survey and estimates on the annual expense for personnel, laboratory, instruments, publication and printing. At the next stated meeting of the Institute resolutions endorsing the plan were approved. A year later the Legislature passed a bill providing for the Second Geological Survey of Pennsylvania.

The City of Philadelphia.

At frequent intervals, The Franklin Institute has been called upon to give expert advice to the City Councils. Only a few of these occasions can be mentioned.

A study of the best methods of paving highways was undertaken at the request of Councils in 1843. The best construction of asphalt, wood and stone pavements was described. Pavements especially suitable for Philadelphia were noted, as well as plans and specifications and the manner of superintending and executing the work. The report was accompanied by a map of Philadelphia, showing the soils and drainage between the two rivers and South and Vine Streets. On another occasion the Institute was requested by the Guardians of the Poor to advise them as to the most effective means of protecting the Alms House from lightning.

In 1883 the report of a committee on the Prevention of Fires in Theatres was presented. The report was printed in the JOURNAL and contains 38 recommendations intended to make places of amusement more safe, nearly all of which have since been adopted—one of these was the familiar asbestos cloth drop curtain. More recently the advice of the Institute was sought on the proper method of preserving the Liberty Bell from further damage.

The interest of the Institute in the problem of a suitable water supply for Philadelphia dates from 1875 when Councils authorized the Mayor to appoint a Commission of five

scientific and practical engineers to be selected from not less than eight persons recommended by the Board of Managers. The commission was organized within a month and made a thorough investigation of the various pumping stations and reservoirs. Examination was made of the Wissahickon, the Perkiomen and the upper Delaware as possible sources of future supply. The Perkiomen reservoir and conduit seemed at the time to be practical. Abstracts of this report were printed in the JOURNAL.

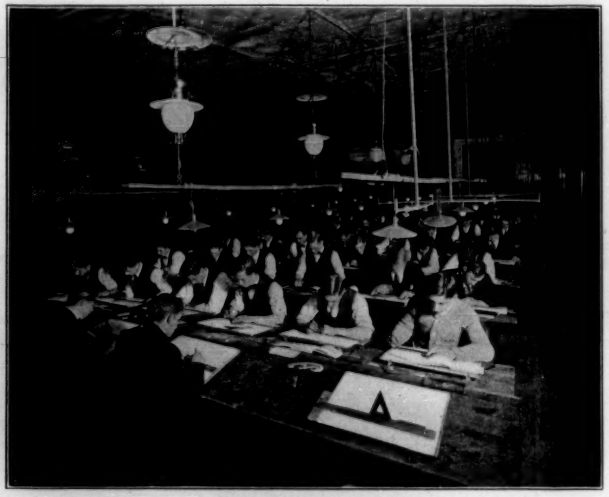
THE LIBRARY AND READING ROOM IN 1880.

From a painting by Colin C. Cooper, Jr.

Seven years later the Institute investigated the pollution of the Schuylkill river and recommendations were published in the JOURNAL. In the same year another city commission selected in part from engineers recommended by the Institute was appointed to study the future water supply and the prevention of waste. The report, published in the JOURNAL, contained recommendations for the installation of machinery in the pumping stations, the completion and extension of

reservoirs, the management of the stations, and the use of meters in factories and large public buildings.

Another study bearing upon the general health of the citizens was that made upon the smoke nuisance which was given consideration in 1887 and again in 1897. In the latter year the investigation was at the request of the Board of Health. As a result of these studies, Philadelphia became a cleaner and healthier place in which to live, and continued so until the suspension of certain ordinances against smoke pollution. The Franklin Institute is represented on the present Air Hygiene Commission of Philadelphia, which is considering similar problems.

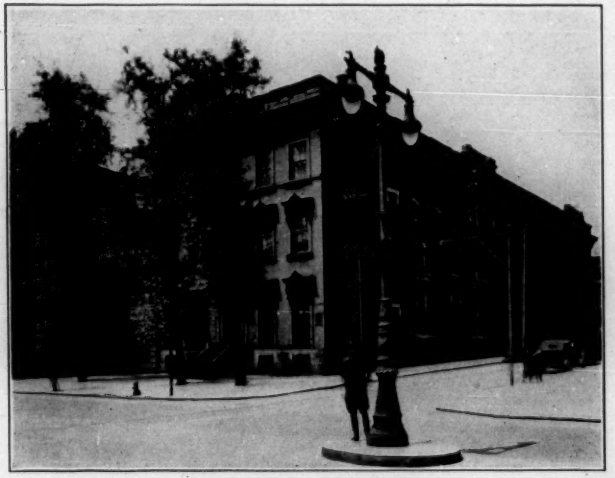


THE DRAWING SCHOOL.
A class in session. Taken about 1907.

EDUCATIONAL SERVICE.

The main contributions of the Institute to the education of the public were made through its day and night schools which were continued to 1923, and through its library which

served as a source of self education for many beginners as well as an invaluable reference for those already engaged in scientific pursuits. Many men distinguished in their fields received their earliest training in the School of The Franklin Institute. Besides instruction in mechanical drawing and basic science, special studies were encouraged in the school. One of the first stenographic schools in the city started in 1876 when Pitman shorthand was taught under the direction of the Actuary of the Institute. Near the end of the last century, departments of Machine Design and Naval Architecture were established.



THE SCHOOL OF DESIGN FOR WOMEN.

From a photograph of the school in its present location, taken several years ago.

The School of Design for Women.

In April 1850 a letter from Mrs. William Peter proposed that The Franklin Institute should establish a School of Design for Women. For several years she had been conducting such a school in her own home but felt that it could

be more effectively managed and supported through the agency of the Institute, which had been engaged in educational work since 1824. It was her plan to train girls to make designs for the products of Philadelphia industry.

The Institute immediately favored the proposal and a committee was formed to take charge of the school. Mrs. Peter and two other women were members of this body. David L. Brown, John Fries Frazer, Frederick Fraley and Samuel Vaughn Merrick were among the officers of the Institute most deeply interested. The Institute rented rooms in No. 70 Walnut Street for the classes which were speedily filled. Classes fell into three divisions, Elementary Drawing and Coloring, the Industrial Department, and the Department of Wood Engravings and Lithography. In the two latter departments the students were enabled to be to a certain extent self-supporting, as many orders were filled by the students and all earnings, except a sufficient percentage to remunerate the school for its expenses, were turned over to the student. The friendly relations existing between the Institute and the industries were of great aid in securing a market for the products of the school.

SCHOOL OF DESIGN
OF THE
FRANKLIN INSTITUTE,
PHILADELPHIA.

WOOD CUTS NEATLY EXECUTED.

☞ ALSO, Designs for Carpets, Paper Hangings, Calicoes, Mousselines, &c., &c., for sale, or made to order, with despatch, and on moderate terms.

Mr. _____

To THE SCHOOL OF DESIGN, Dr.

BILLHEAD OF THE SCHOOL OF DESIGN.

From a wood cut made by a pupil in 1851.

The school continued under the auspices of the Institute until April 1853 when an independent charter was obtained. All funds and materials in the custody of the committee were turned over to the new school, and its pupils were allowed to continue in the use of the library. The first president of the new organization was Elliott Cresson, a member and benefactor of the Institute. The Franklin Institute has observed with pleasure the growth of the school which it once fostered and which is now merged with the Moore Institute of Art, Science and Industry. It is interesting to note that during the entire period while John Sartain was Director or Vice-President of the School of Design (1868–97), his son Samuel Sartain was Manager or Treasurer of The Franklin Institute (1865–1906).

The Pennsylvania Museum and School of Industrial Art.

The Institute encouraged the formation of this school, and the proposal received the hearty endorsement of the Board of Managers at a meeting in September 1875. Coleman Sellers, a president of The Franklin Institute, was active in planning the organization of the new school. Three months later the Board received an invitation to name a member of the Board of Trustees of the new School of Industrial Art. This privilege was continued and in that manner the Institute had a voice in the management of the school for a decade. In the spring of 1879 the Institute offered to allow the classes of the School of Industrial Art to be conducted in the building of the Institute. This offer was accepted and for a little over a year classes of the two organizations were held under the same roof, and the library and other facilities of the Institute were shared equally. During this period the enrollment of the School of Industrial Art increased tremendously.

Scientific Societies.

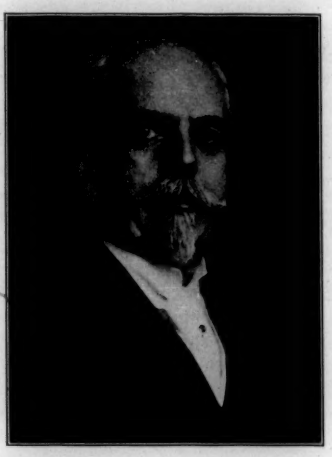
The Franklin Institute played a part in the origin of two national scientific societies which are today of great size and influence. The first of these, The Association of American Geologists, was instituted in the hall of The Franklin Institute, by eighteen founders of whom seven were members of the Institute. Eight years later the name of the society was

changed to The American Association for the Advancement of Science.

The American Institute of Electrical Engineers was not founded in Philadelphia, but the occasion of its foundation was the Electrical Exposition of The Franklin Institute in 1884. The call for the organization meeting stated that "An International Electrical Exhibition is to be held in Philadelphia next autumn, to which many of the famous foreign electrical savants, engineers, and manufacturers will be visitors," and went on to suggest that a national electrical society should be formed to receive them.

The James Mapes Dodge Lecture Foundation.

A recent activity has been the establishment of Christmas Week lectures for young people. These lectures are designed



JAMES MAPES DODGE, 1852–1915.

Inventor and engineer. For many years actively interested in The Franklin Institute, of which he was a Vice-President from 1903 to 1915.

to bring to the Institute each year a scientist who is not only distinguished in his field, but is able to present his subject

with a multitude of demonstrations and in a manner that will hold the interest of young people or of adults untrained in science.

The first lectures of this series were delivered during Christmas Week in 1926 and at the close of the course Mrs. James Mapes Dodge established the James Mapes Dodge Lecture Foundation as a memorial to her late husband, a long time member of The Franklin Institute and a vice-president of the Institute at the time of his death. In this way the continuance of this interesting series is assured and will serve to perpetuate the memory of a great inventor and engineer and a valued member of the Institute.

SERVICE TO SCIENCE AND INDUSTRY.

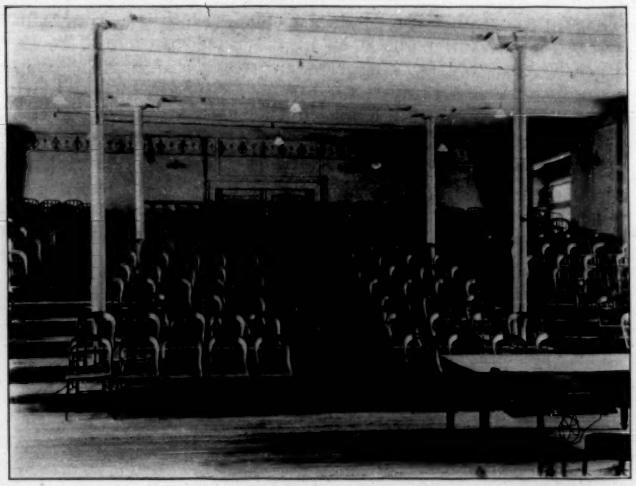
In practically every field of endeavor that it touched, the Institute aided directly or indirectly the advances of industry and science. Through its schools by the training given to young men, through the library by the opportunity afforded for utilizing the experience of others, through the JOURNAL by carrying, to the four quarters of the earth, word of the discoveries resulting from American ingenuity, and through other channels The Franklin Institute has made its contribution.

Lectures.

The lectures given before the Institute have served several purposes. They were a means of enabling the members to keep informed of the progress of science and technology. They served as a form of recognition of important work well done. In many instances they were the first public announcement of an important technical or scientific advance. To enumerate more than a few of these would be an unwarranted expansion of this article.

The talking machine was demonstrated by its inventor Emile Berliner in 1888. A workable voting machine was shown in 1901 and earned for its inventor the John Scott Medal. An automatic telephone system was installed and in operation in the lecture hall in 1909, and in 1916 the first public demonstration of transcontinental telephony was given in this hall. On this occasion each chair was supplied with a telephone receiver and those present were able to listen to

the conversation of the chairman with members of the Institute and others in San Francisco. In 1885, W. N. Jennings showed the first successful photographs of lightning whereby it was demonstrated that it travels through a curved



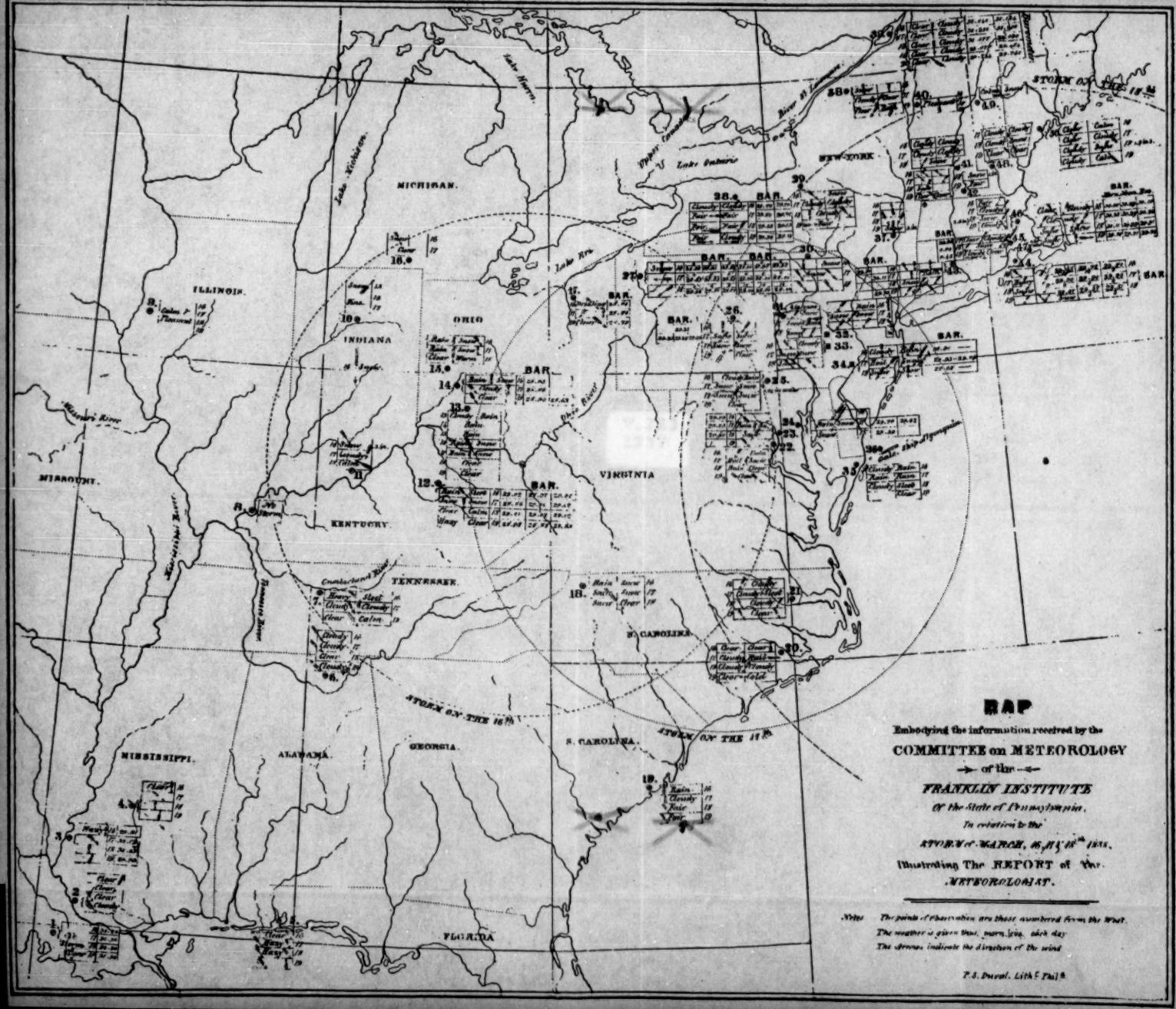
THE LECTURE HALL.

Showing the hall as it appeared near the beginning of the twentieth century. Many important discoveries were announced or demonstrated for the first time in this room.

rather than an angular path, and when a new method of taking motion pictures in color was developed by the Eastman Kodak Company, it was first described to the public at a meeting of the Institute in 1928.

Journal.

The Journal of The Franklin Institute has maintained a high scientific standing throughout its career and it is today the oldest technical journal published in the United States, having been issued monthly for 111 years. It has carried patent records, comments on inventions and on fundamental


MICHIGAN.
ILLINOIS.
INDIANA
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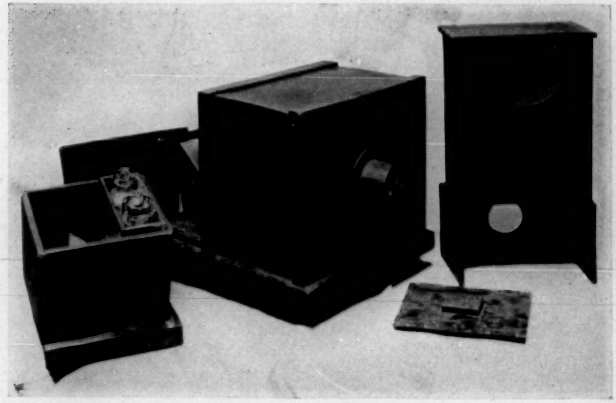
KENTUCKY
VIRGINIA
TENNESSEE.
N. CAROLINA
S. CAROLINA.
GEORGIA.
ALABAMA.
MISSISSIPPI.
FLORIDA
NEW-YORK
STORM OF THE 18th
STORM ON THE 16th
STORM ON THE 17th
BAR.
MAP
Embodying the information received by the
COMMITTEE on METEOROLOGY
of the
FRANKLIN INSTITUTE
Of the State of Pennsylvania,
In relation to the
STORM of MARCH, 16, 17, 18th 1834.
Illustrating The REPORT of the
METEOROLOGIST.
Note. The points of observation are those numbered from the West.
The weather is given thus, morn. eve. each day.
The arrows indicate the direction of the wind
P. S. Duval. Lith.r Phil.a

science and the results of new investigations for all that time. The work of the special committees of the Institute and many of the lectures have been published therein, together with numerous papers submitted for publication from all over the world.

An important paper nearly a century ago was the publication of the full translation of the paper presented to the French Academy by Daguerre entitled "Practical Description of the Process Called the Daguerreotype, which Consists in the Spontaneous Reproduction of the Images of Natural Objects in the Camera Obscura, not with Their Colours, but with Great Delicacy in the Graduation of the Tints."



DAGUERREOTYPE CAMERA AND OUTFIT.

These were made by Joaquim Bishop in Philadelphia from Daguerre's description published in the JOURNAL OF THE FRANKLIN INSTITUTE. It is believed to be the oldest camera in the United States.

This was the first description of a workable photographic process printed in America and it created a sensation. Probably the first picture taken in this country was by Joseph Saxton, who with the aid of a camera improvised from a cigar box obtained a likeness of the Philadelphia High School and the State Arsenal from a window of the Mint. Robert

Cornelius is credited with the first successful photographic portrait of a living person made in this country. Both of these gentlemen were members of the Institute and showed the results of their experiments at an early meeting. Articles in the JOURNAL by Dr. John W. Draper and others helped to create in Philadelphia the skilled and enthusiastic group of amateurs which has existed in the city from the earliest days of photography.

Exhibitions.

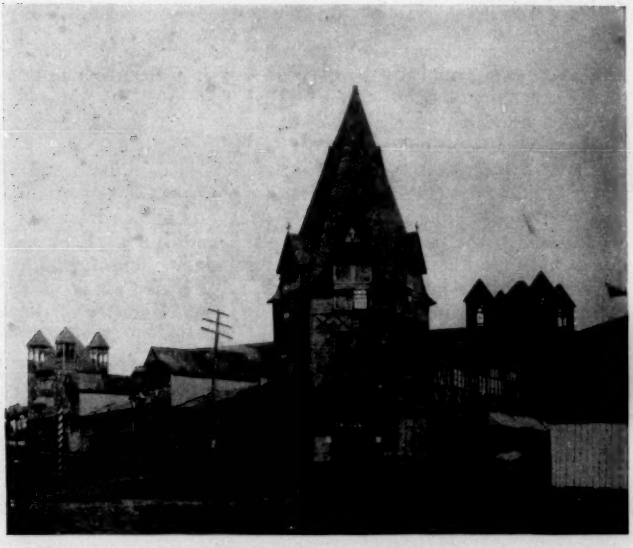
The general character of the annual and biennial exhibitions that were held up to the year 1858 has been indicated in the preceding article. That of 1840 was especially notable for the Daguerreotypes displayed.

In 1869 a committee of The Franklin Institute was organized to interest the proper authorities in a plan to hold an exhibition on the centennial anniversary of American independence. The activities of this committee resulted eventually in the passage by Congress, in March 1871, of an Act to provide for the Centennial Exhibition. The Franklin Institute and its members played an important part in this exhibition, but it is not to be considered as an activity of the Institute, whose foresightedness in making the proposal, however, doubtless contributed largely to its success.

In 1874, two years prior to the Centennial, occurred the fiftieth anniversary of the foundation of the Institute. This was seized upon as an opportunity to reëstablish among manufacturers the habit of exhibiting in Philadelphia, to serve as a curtain raiser, so to speak, for the Centennial. The Pennsylvania Railroad placed its old building at Thirtieth and Market Streets at the disposal of the Institute for exhibition purposes. The affair was a great success with over 1200 exhibitors and an attendance of over 268,000. A notable contribution of this exhibition to the joy of American life was the introduction of the ice cream soda, which was on sale for the first time and soon gained immense popularity.

Successful, however, as was the exhibition of 1874, it was eclipsed in brilliancy and in value from the educational and technical standpoint by the Electrical Exhibition of 1884, which by Act of Congress was made international in character. This was undertaken without financial aid from the

state or nation, and was the first exhibition devoted to the electrical industry held in this country. Exhibitors naturally were few, but they showed their goods in great detail in order to interest and arouse the public. The attendance exceeded 299,000, and men of such eminence in the field as Lord Kelvin, Sir Oliver Lodge, Alexander Graham Bell,



THE INTERNATIONAL ELECTRICAL EXHIBITION.

This building was erected for the purpose at Thirty-Second Street and Lancaster Avenue, in 1884.

S. P. Langley, Elihu Thomson, E. J. Houston, Thomas A. Edison and Sir James Dewar were interested spectators or participants.

The Novelties Exhibition in the following year, and the National Export Exposition held in 1899 with the coöperation of the Commercial Museum, complete the list of great exhibitions of The Franklin Institute, until the erection of the

present building. At the present time, instead of occasional exhibitions, there is shown in the Museum a continuous but constantly changing display of the products of industry and invention and of the basic underlying sciences.

Awards.

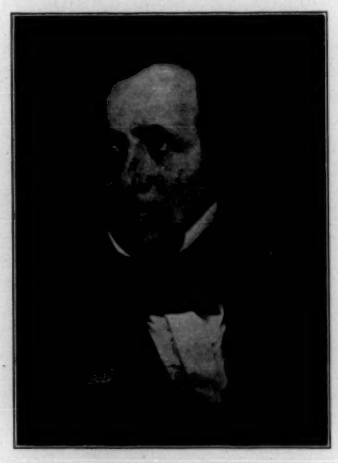
The Committee on Science and the Arts has devoted its energies to investigating and reporting upon new inventions and discoveries. As awards became available for distribution by the Board, it has been guided by the recommendations of the Committee. In a little more than a century, 998 honors have been thus awarded, including six hundred in the sole custody of the Institute. For a period of eighty-four years the John Scott medal was awarded by the City on the advice of the Institute. Since 1918 the Institute has not participated in this particular award. At the present time the Committee makes recommendations on the award of eight medals, one premium, and Certificates of Merit.

The Elliott Cresson Medal is awarded either for some discovery in the arts and sciences, or for the invention or improvement of some useful machine, or for some new process or combination of materials in manufactures, or for ingenuity, skill or perfection in workmanship. It was founded by Mr. Cresson in 1848 and has been awarded 165 times. Among the recipients of this medal may be found the names of Bell, Bridgman, de la Cierva, Crookes, the Curies, De Forest, Diesel, Emil Fischer, Henry Ford, W. J. Hammer, Frederick Ives, C. F. Jenkins, Chevalier Jackson, the Lumières, Michelsen, Ramsay, Rayleigh, Rutherford, E. A. Sperry, Jr., Tesla, Elihu Thomson, Vauclain, Welsbach, H. W. Wiley and Orville Wright.

The Boyden Premium of $1000 is to be awarded to any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity. This was established in 1859 by Uriah A. Boyden and was awarded in part in the year 1907.

The Edward Longstreth Medal was established by Edward Longstreth in 1890 and by Charles Longstreth, his son, in 1913. It has been awarded 219 times to firms or individuals

in recognition of meritorious work in science and the industrial arts. Among these are Christopher A. Becker, T. A. Edison, W. E. Hoke, H. E. Ives, M. E. Leeds, A. H. Meeker, Edwin Ruud, Sharples Specialty Company, H. C. Snook, E. A. Sperry, Jr., Welsbach Light Company, Williams, Brown & Earle, Yawman and Erbe Manufacturing Company and others.



ELLIOTT CRESSON.

Donor of the Elliott Cresson Medal Fund and in other ways a benefactor of the Institute. He was the first President of the School of Design for Women under its own charter.

The Howard N. Potts Medal was established in 1906 by the bequest of Howard N. Potts to be awarded for distinguished work in science or the mechanic arts. It has been awarded among others to W. D. Coolidge, Ulric Dahlgren, Marion Eppley, E. V. McCollum, Ralph Modjeski, Igor Sikorsky, and C. T. R. Wilson.

The Franklin Medal is the highest award in the power of the Institute to bestow. It was established by Samuel Insull in 1915 and has been awarded 44 times for signal and eminent service in science. Arrhenius, Bragg, Dewar, Edison,

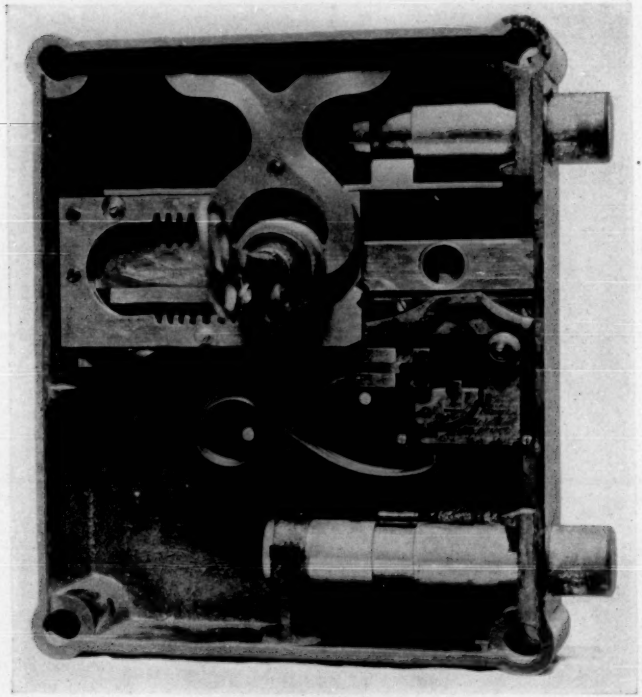
Einstein, Lorentz, Marconi, Michelsen, Planck, Richards, Rutherford, Thomson, Weston, Whitman, Wright, and Zeeman, are among the distinguished scientists so honored.

THE FRANKLIN MEDAL.

The highest award offered by the Institute.

The Clark, Levy, Henderson, and Wetherill Medals were all established more recently and reference will be made to them in the next article.

In thus honoring those who have made important contributions to science or industry, the Institute, of course, honors



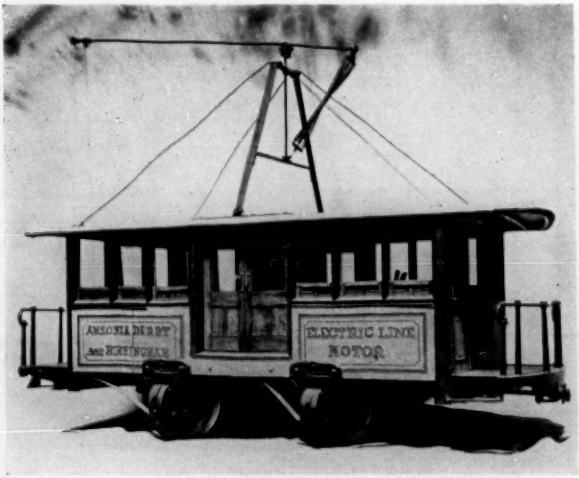
YALE LOCK.

Made by Linus Yale, Jr., of Philadelphia in 1855. "Presented to Wm. Morris Davis from his friend the author. Presented on the day he picked The Newell Lock. October 15, 1855, Newport, R. I."

itself. Many of these awards, however, were made prior to the greatest work of the recipients and the Institute gave the encouragement of its approval to the inventor.

Research.

To a great extent all the various special investigations of the Institute have consisted of research work, for the objects of these studies have been to explore and report upon fields in which information was lacking. Research into pure science has always received encouragement through the JOURNAL, the Library, and the various awards recommended by the Committee on Science and the Arts.



ELECTRIC LOCOMOTIVE OF 1888.

Model of the original Van Depoele electric motor and car for hauling passenger and freight cars in the lower Naugatuck Valley, Connecticut.

During and immediately following the International Electrical Exhibition of 1884, there were conducted the most complete and elaborate tests of electrical equipment ever attempted up to that time. With all the most important types of electrical apparatus then known in the commercial world readily at hand, the opportunity was unusual and was not neglected. Reports of these tests appeared in the

JOURNAL and were printed in pamphlet form. These tests covered efficiency and duration tests of electric lamps, tests of dynamos, electric signalling and recording apparatus, telegraphs, batteries and so forth.

Eclipse Expeditions. Expeditions have been sent to make observations during total eclipses of the sun which could be observed without too great an outlay for travelling expenses. In 1869 an expedition under the direction of

ECLIPSE EXPEDITION OF 1869.

A few of the twenty observers. The seated figure is Henry Morton, the leader of the expedition.

Henry Morton, made observations at Mount Pleasant, Iowa, of the eclipse which occurred on August seventeenth of that year. The telescopes were borrowed, and the transportation furnished by the railroad companies. Complete reports of the expedition, including a photograph taken during totality, were published in the JOURNAL. Again in 1932 an expedition under the direction of James Stokley, was sent to Conway, New Hampshire, to observe the eclipse of August thirty-first.

The Bartol Research Foundation. In 1918 Henry W. Bartol, a leader of industry in Philadelphia, bequeathed to The Franklin Institute his residual estate, for the establishment and operation of a laboratory for research in the physical sciences and solution of problems of a scientific character. The bequest finally amounted to more than a million dollars.

Active research work commenced in 1925 in four dwellings owned by the Institute on Nineteenth Street at Race. Two years later Dr. W. F. G. Swann of Yale, who had formerly served with a Professor Adams of Princeton as an advisory committee, came to the Foundation as Director. The investigations of the Bartol Research Foundation have dealt with fundamental problems of electricity, chiefly in the field of nuclear physics and especially that branch of it dealing with cosmic rays. In the course of these studies the phenomena of cosmic rays have been observed in various locations over the surface of the earth and in the atmosphere up to elevations within the region known as the stratosphere.

In 1928 arrangements were made for the erection of a building to house the Bartol Research Foundation on the campus of Swarthmore College. The arrangement has been most satisfactory and the sensitive instruments needed for the work are located in a region less troubled by vibrations and other disturbing causes than could be found within the city.

The Biochemical Research Foundation. This organization became affiliated with The Franklin Institute in 1935. Under this Foundation and the direction of Dr. Ellice McDonald, an active group of investigators are studying various problems of a biochemical nature, especially in the field of cell growth and reproduction. It receives its support from a prominent philanthropist who wishes to encourage research in this field. The laboratories are located on South Thirty-Sixth Street.

MEN AND MEANS.

The activities of an Institute do not run of themselves. They are but the acts of many men, divided, perhaps, by the passage of time, but united in purpose. Nor can these be carried on without expense, and credit is due to those who have supported the work of the Institute as well as to those

who were the agency of its accomplishment. Both groups have been people of vision. They have looked ahead and seen what would need to be done and have then set about finding a practical method of action. That the Institute has survived to its venerable age is but an indication that, in its purposes and tradition, it has appealed to both groups as the logical instrument through which to achieve the ends desired.

FRANKLIN INSTITUTE CURRENCY.

Issued in 1837 and 1838 with a view to purchasing a new site.

The Institute for the most part proceeded slowly as befitted an organization with limited funds. Its useful and humble purposes frequently failed to attract the fancy of those considering charitable gifts or bequests. The library, however, was the recipient of a number of bequests and the

general funds of the Institute were frequently enriched by handsome gifts from members of families that by their traditions and occupations were able to properly appraise the contributions of The Franklin Institute to society and the likelihood of its value in the future.

The great outpouring of generous assistance that made possible the erection of the great Memorial to Benjamin Franklin, in which is housed the Museum of The Franklin

THE READING ROOM OF THE LIBRARY.

As it appeared just before the books were removed to the new building on the Parkway.

Institute, is to be deferred to the succeeding article. The conception of this idea, however, originated in the past century when funds for building purposes were first set aside. It stepped forward in 1907 when the Board of City Trusts agreed, under certain conditions, that the funds left to the City in trust by Benjamin Franklin should go toward the erection of the new building. In a report of that time the names of the Pepper, Weightman, Harrison, Shippen, Graff

and Ware families appear conspicuously as donors to the funds of the Institute.

The Franklin Institute stood in 1924 at the close of the first century of its service. Much had been accomplished, and a sound foundation had been laid as a basis for future service. The city had increased tenfold in population and its throngs of industrial establishments, its thousands of workers and technical experts, were an indication that the possibility of usefulness of the Institute had in reality only begun. The cramped quarters of the old building were inadequate for the throngs to which the Institute could and should be of service. It was necessary, if the purposes of the founders were to be fulfilled, that the Institute should find a method whereby its doors could be opened to tens of thousands of industrial workers and young people, as well as to those of special technical training.

The method, the men and the means were close at hand.

[*This is the second part of the Story of The Franklin Institute by Dr. Wright. The third installment "Renewed Vigor" will appear in the June number.*]

A NEW MATURITY TEST OF PEAS.[1]

BY

S. L. JODIDI, Ph.D.,

Physiologist, Bureau of Plant Industry, United States Department of Agriculture.

INTRODUCTION.

Like the tomato and sweet potato, the pea (*Pisum sativum*) is a favorite vegetable and hence a fairly frequent article of our dietary. However, there is all the difference in the world between young unripe peas and completely ripe or old peas. While the former are characterized by a high sugar and low starch content, the reverse is true of the latter which have a high starch and low sugar content. Whereas young peas are favored for their sweetness, palatableness and flavor, old peas known to be lacking in these qualities are not liked quite so well. For these reasons it is not surprising that young peas command very much higher prices than older peas. But while the quality of peas plays a big role from a culinary standpoint, the yield of peas per acre is important from an economical point of view. It is here that the opinions and interests of pea growers and canners clash, the former offering fully mature peas because of their greater yield and the latter demanding young unripe peas because of their superior qualities for canning purposes. Owing to this conflict of interests it is but natural at present to find in practice both extreme types of pea crops that are so to speak ideal from the viewpoint of growers on the one hand, and from that of canners on the other.

METHODS OFFERED FOR JUDGING THE QUALITY OF PEAS.

In the decision of the maturity of peas one inherent difficulty is involved. It is this: When peas approach the stage of maturity they undergo changes quite rapidly. The younger peas which, as stated, have a higher sugar and lower starch content as well as flavor and palatableness, are converted rather quickly into older peas which lack those good qualities.

[1] U. S. Patent applied for.

The rapid changes coupled with the importance of the American pea industry amounting to 25 million dollars per annum (22) made it imperative to find a method for ascertaining the stage of the quality of peas best suited for harvesting for the market and especially for canning. Of the various methods offered the more important only can briefly be considered here.

(*a*) The "maturity index" of Boswell (4, 5, 6) is computed by adding the products obtained by multiplying the percentage of peas in each size by the size number.

(*b*) The "puncture test" of Sayre, Willaman, and Kertesz (19, p. 7) measures the firmness of the seed coat, the firmness increasing with age of the peas.

(*c*) The "crushing test" of Sayre, Willaman, and Kertesz (19, p. 11) measures the load necessary to crush the entire pea, the load rising with age of the peas.

(*d*) The "quality index" of Horsfall, Kertesz, and Green (10, p, 835) is calculated by adding the products obtained by multiplying the average crushing load of each size (except size 1) by the percentage of peas in that size.

(*e*) The "starch-sugar ratio" (1, p. 49; 4, 6) involves the estimation of moisture, sugars, and starch in the material, a lower or higher ratio pointing to younger or older peas.

(*f*) The "protein-nonprotein nitrogen ratio" (12, pp. 728–729) involves the determination of moisture, total, protein, and nonprotein nitrogen in the peas, a lower ratio indicating younger peas, and vice versa.

(*g*) The "index of ripening" (18) involves the estimation of starch, sugar, cellulose, soluble and insoluble nitrogen.

(*h*) The "brine method" (7, p. 10) employs salt solutions of different strength. The number of peas that float or sink in the solutions indicate the degree of their maturity.

CHARACTERISTICS OF THE METHODS OFFERED.

Each of the methods described was undoubtedly more or less useful as long as a better mode of work was not available. However, experience has shown that method (*a*), which is the simplest of all, does not give consistent results and appears therefore not to be quite satisfactory. The methods (*b*), (*c*), and (*d*) involve the use of a puncture tester or crusher tester whose handling requires experience. Furthermore,

since they test but a small number of peas, they can hardly indicate the maturity of pea crops uniformly and consistently. The methods (*e*), (*f*), and (*g*), considered as standard methods because they are based on chemical analysis, give a good index of maturity. Yet the maturity estimation by each of these methods takes two to three days during which time the maturity of a pea crop progresses so much as to render the chemical analyses useless. Method (*h*) is apparently better than the other methods, but requires also too much time.

THE NEW MATURITY TEST OF PEAS.

The writer's new "maturity test," which is based on the specific gravity of peas, combines extraordinary rapidity with great accuracy and simplicity. So rapid is it that it takes but *15 to 20 minutes to make a maturity test as compared with 2 to 3 days required by the standard methods* (*e*), (*f*), *and* (*g*)*; so accurate is it that duplicate maturity tests agree within a few hundredths of one per cent. as compared with the standard methods whose duplicates deviate from each other 1 to 5 per cent. and more;* so simple is the maturity test that its handling requires no technical training or experience.

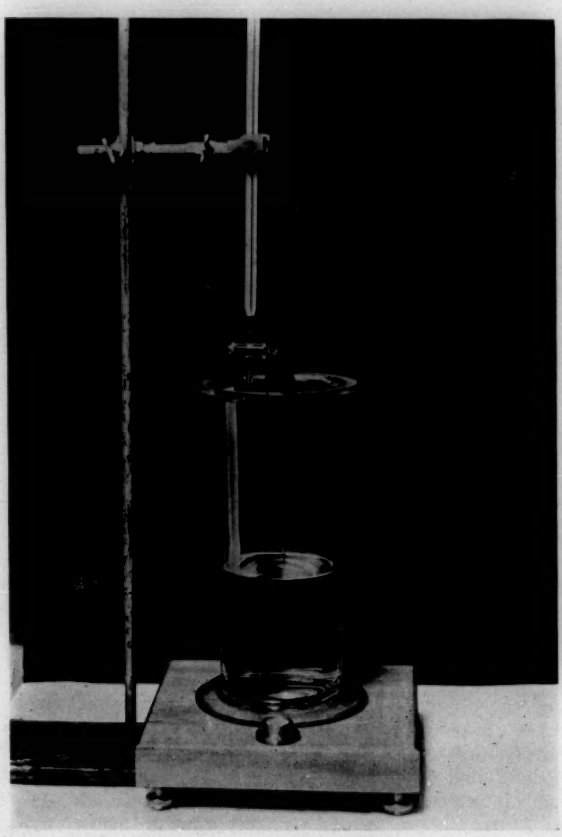
PEAS AS COMPARED WITH POTATOES.

The new maturity test, which is based on the specific gravity of peas, is somewhat similar to the method applied to potatoes (2, 16, 17). But while peas (11, 13) and potatoes (20) have in common that their nonprotein nitrogen is made up chiefly of acid amides, amino acids, and polypeptides, they show striking differences in physical, chemical, and other respects. Thus, the weight of a pea ovule is about one-third to one-half gram, that of a potato tuber is one-third to one pound, the ratio of their weights being from 1 : 450 to 1 : 900; the tuber contains practically starch only, with but a trace of sucrose, while the pea contains, besides starch, sugars up to 20 per cent. (dry basis); tubers are known to contain about 2 per cent. of protein (21, p. 348) as against double that amount present in peas (12, pp. 728–733); potatoes apparently contain no organic acids, while peas contain citric, pyrrolidonecarboxylic, and other acids (14, 15). These great differences made it necessary to use apparatus other than those applied to potatoes, or to essentially modify some of them as well as the manner of work.

THE MODE OF WORK ACCORDING TO THE NEW MATURITY TEST.

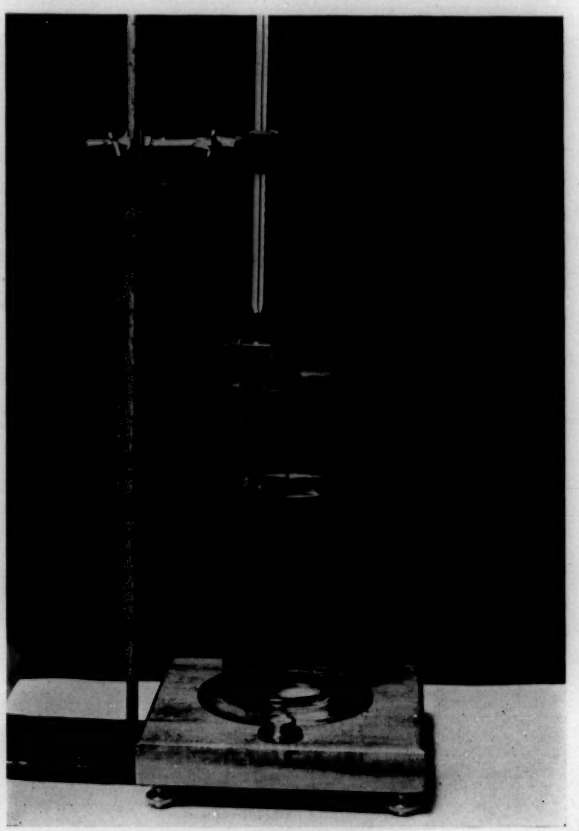
A glass cylinder (C), having the capacity of 2 to 3 liters, and two measuring brass rods (R and R') of unequal length are

FIG. 1.



used in this test. As a preliminary step the volumes from bottom of cylinder *C* (which stands on a leveling board) to the tip of the long measuring rod (Fig. 1), and from the tip of this rod to the tip of the short measuring rod (Fig. 2) are

FIG. 2.



ascertained. In our case these were found to be equal to 1031.8 and 714.4 cubic centimeters, respectively. The second volume (714.4 cc.), once ascertained, serves as basis for any number of specific gravity estimations.

FIG. 3.

DETERMINATION OF THE SPECIFIC GRAVITY OF PEAS.

The actual estimation of the specific gravity of peas is made as follows: The cylinder adjusted to stand vertically on a leveling board (see Fig. 3), receives rapidly the entire volume of water from a pipette having the capacity of 1030 cubic centimeters. This is followed by careful addition of water from a burette until the water surface just contacts the needle-sharp tip of the long rod, which is now removed. Next 500 grams of peas, weighed out in a counterpoised copper beaker, are at once transferred to the cylinder so as to avoid spattering. Now the short rod R' is placed on the cylinder and 220 cubic centimeters of water is added by means of a pipette, followed by careful addition of water from a burette (say, 1.3 cc.) until the needle-fine rod tip just reaches the water surface. So delicate is this manipulation that a final *single* drop of water added to the cylinder is sufficient to effect that contact. The test is now completed.

CALCULATION.

On subtracting the volume of water added (220 cc. + 1.3 cc.) from the volume between the tips of the two measuring rods (714.4 cc.) there is obtained 493.1 cubic centimeters which represents the volume occupied by 500 grams of peas. Hence, 500/493.1 or 1.0140 is the specific gravity of the pea sample. This simple calculation may be rendered superfluous by the preparation of a table which gives the specific gravities corresponding to the volumes occupied by the peas.

It may be mentioned here that under "grade 2" are understood peas which will not pass through a screen having round holes nine thirty-seconds of an inch in diameter, but will pass through holes ten thirty-seconds of an inch; under "grade 3," peas unable to pass through holes ten thirty-seconds of an inch, but able to pass through holes eleven thirty-seconds of an inch, while with "grade 4" are designated peas which cannot pass through holes eleven thirty-seconds of an inch, but are able to pass through holes twelve thirty-seconds of an inch.

The peas used in this work were grown on the grounds of the Arlington Experimental Farm, Rosslyn, Virginia, during the season of 1934.

ANALYTICAL METHODS EMPLOYED.

Fresh peas, cut into slices, were used for the moisture estimation which was effected in an electric oven at 105° C. until constant weight was obtained.

For all other estimations the peas were preliminarily dried at 65° C. for about 18 hours, ground, passed through a 40-mesh sieve, and placed in air-tight containers.

For the determination of carbohydrates two grams of the ground peas were extracted in a Soxhlet extraction apparatus with 60 per cent. alcohol for at least 4 hours. The extract obtained, on being freed from alcohol on the water bath, was transferred to a 250 cc. flask, clarified with 2 cubic centimeters of 20 per cent. neutral lead acetate solution, made up to the mark and filtered.

For the estimation of reducing sugars 100 cc. of the filtrate was usually transferred to a 300 cc. Erlenmeyer flask to which 20 cc., each, of Bertrand's solutions A (copper sulfate) and B (Rochelle salt), was added and boiled for 3 minutes. On allowing the cuprous oxide to settle the supernatant liquid was decanted on a Soxhlet asbestos filter with suction. Upon washing well the cuprous oxide in the flask and on the filter with hot distilled water, the filter was taken from the suction flask which was rinsed out with water to remove any copper present. Now 20 cc. of Bertrand's solution C (ferric sulfate) was put into the Erlenmeyer flsak to dissolve the cuprous oxide. This solution was next poured on the Soxhlet filter (placed on the suction flask) to dissolve its cuprous oxide. Flask and filter were then washed with hot water to get all the copper solution into the suction flask. The combined liquid was now titrated with Bertrand's standard solution D (potassium permanganate), the result being calculated as glucose (3, 8).

The sucrose estimation was made in 75 cc. of the solution, as used for determination of reducing sugars. The inversion was effected in a 4 per cent. hydrochloric acid solution according to Herzfeld's method (9), namely at 67 to 70° C. for not more than 10 minutes. On cooling and neutralization with sodium hydroxide, the inverted solution was made up to 100 cc. In 50 cc. portions of this the total sugar, estimated according to Bertrand's method, was calculated as invert sugar.

By subtracting the percentage of reducing sugars found as such from that of the total sugars and multiplying the difference by 0.95 the percentage of sucrose was obtained.

The starch was determined in the residue which remained after the 2 grams of peas had been extracted with 60 per cent. alcohol. That residue, hydrolyzed with a 2 per cent. hydrochloric acid solution for two hours, was cooled, neutralized, made up to 250 cc., and filtered. In 10 cc. portions the sugar estimated by Bertrand's method as glucose and multiplied by the factor 0.9 gave the percentage of starch. Mention may be made of the fact that, aside from starch, peas contain also other hydrolyzable polysacchorides like sucrose, cellulose, hemicelluloses, and dextrin. However, the extraction with alcohol before the hydrolysis has freed the peas from sugars quantitatively, though not completely from dextrin. And while the hemicelluloses have been hydrolyzed by the 2 per cent. hydrochloric acid solution, at least in part, cellulose could not be affected by so weak a solution. These considerations coupled with the circumstance that the described method of estimating starch was used in a previous publication (12) made it advisable to employ the same method in this work in order to render the results comparable.

THE SPECIFIC GRAVITY OF PEAS AS COMPARED WITH THE STARCH-SUGAR RATIO.

The question naturally arises: Does the maturity test based on the specific gravity of peas actually give the stage of ripeness of a pea crop? The answer to this question can best be given by a comparison of the specific gravities of peas with the experimental results obtained by a standard mode of work, such as the starch-sugar ratio method which, as mentioned already, gives a very good index of the maturity of a pea crop. Moreover, the question can and will also be answered on the basis of theoretical considerations. Thus, the close relationship between the specific gravity of peas and their starch-sugar ratio follows from a contemplation of the following facts. It is known from previous work (12) and that of others that fresh peas have about the following composition: water, 75 per cent.; ash, 0.9 per cent.; fat (oil), 0.4 per cent.; sugar, 3.2 per cent.; starch, 9.0 per cent.; protein, 6.0 per cent.; fiber, 5

per cent. While the specific gravity is made up of all these constituents, it is evident from the figures cited that by far the greatest factor influencing the specific gravity of peas is water (whose sp. gr. = 1), followed by starch (whose sp. gr. = 1.63). It has also been established that, as a rule, grade 2 of peas has more water but less starch than grade 3, and that grade 3 has more water but less starch than grade 4. In other words, peas of larger grade or maturer peas, which are known from a previous publication (12) to have more starch and less sugar, must necessarily have a higher specific gravity because of their lower water and higher starch content. Equally, peas of smaller grade or less mature peas, known to have more sugar and less starch, must necessarily have a lower specific gravity because of their higher water and lower starch content, all of which is actually the case. Thus, solely on the basis of the chemical composition of peas we come logically to the conclusion that there is a very striking relationship between specific gravity on the one hand, and water, sugar, and starch content on the other.

DISCUSSION OF THE EXPERIMENTAL RESULTS OBTAINED WITH PEAS OF THE 1934 SEASON.

Let us now consider the data on peas secured in 1934. The table shows that, without a single exception, grade 2 has a higher water percentage and a correspondingly lower dry-matter percentage than grade 3, and that grade 3 has likewise a higher water but a lower dry-matter content than grade 4. For instance, nos. 7, 8, 9, planted April 20 and picked June 11, and representing grades 2, 3, and 4, have gradually decreasing water percentages (77.29, 73.00, 70.28) and correspondingly increasing percentages of dry matter (22.71, 27.00, 29.72). Now leaving out of consideration the reducing sugars whose quantities are so small as to be negligible, it will be observed that, broadly speaking, the sucrose percentage is directly proportional to the water content and inversely proportional to the dry matter content, while the reverse is true of the starch which is directly proportional to the dry matter but inversely proportional to the water content. For example, nos. 16, 17, 18, planted April 30 and harvested June 18, and representing grades 2, 3, 4, show gradually decreasing sucrose percentages

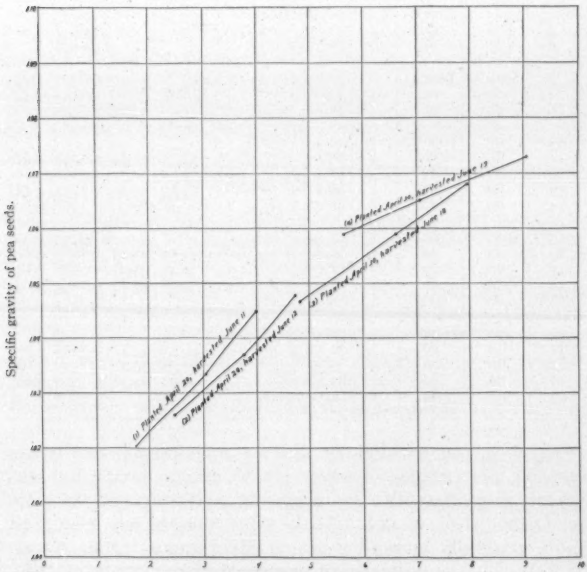
TABLE SHOWING THE CHEMICAL COMPOSITION OF PEAS OF THE ALASKA VARIETY IN 1934.

Analysis No.	Time of Planting	Time of Picking	Grade No.	On Fresh Weight Basis		On Water-free Basis			Specific Gravity	Starch/ Sugar Ratio
				Water %	Dry Matter %	Reducing Sugars %	Sucrose %	Starch %		
1	April 9	June 6	2						1.0187	
2	do	do	3						1.0274	
3	do	do	4						1.0373	
4	do	June 7	2	78.22	21.78				1.0259	
5	do	do	3	73.99	26.01				1.0341	
6	do	do	4	70.75	29.25				1.0445	
7	April 20	June 11	2	77.29	22.71	0.21	17.72	30.79	1.0209	1.74
8	do	do	3	73.00	27.00	0.25	12.38	38.00	1.0331	3.07
9	do	do	4	70.28	29.72	0.17	10.81	43.16	1.0447	4.00
10	do	June 12	1	81.42	18.58					
11	do	do	2	79.02	20.98	0.17	13.97	34.54	1.0256	2.47
12	do	do	3	71.15	28.85	0.21	10.20	38.36	1.0367	3.76
13	do	do	4	69.21	30.79	0.12	8.50	40.30	1.0484	4.74
14	do	do	5	66.74	33.26					
15	April 30	June 18	1	73.37	26.63					
16	do	do	2	71.80	28.20	0.12	8.84	42.49	1.0473	4.81
17	do	do	3	68.09	31.91	0.13	6.95	45.94	1.0586	6.61
18	do	do	4	66.04	33.96	0.11	6.02	47.85	1.0679	7.95
19	do	do	5	65.98	34.02				1.0689	
20	do	June 19	1	73.58	26.42					
21	do	do	2	71.26	28.74	0.25	7.37	41.37	1.0589	5.61
22	do	do	3	64.24	35.76	0.18	6.15	43.51	1.0650	7.07
23	do	do	4	63.56	36.44	0.13	4.89	44.32	1.0732	9.06
24	do	do	5	63.52	36.48				1.0827	

(8.84, 6.95, 6.02) which are directly proportional to the decreasing percentages of water (71.80, 68.09, 66.04) and inversely proportional to the increasing percentages of dry matter (28.20, 31.91, 33.96). At the same time the nos. 16, 17, 18 show gradually increasing starch percentages (42.49, 45.94, 47.85), which are directly proportional to the increasing percentages of dry matter (28.20, 31.91, 33.96), but inversely proportional to the decreasing water percentages (71.80, 68.09, 66.04). But a matter of the greatest importance is the fact that the specific gravity is directly proportional to the starch and inversely proportional to the sucrose content. For instance, nos. 21, 22, 23, i.e., grades 2, 3, and 4, have gradually

rising specific gravities (1.0589, 1.0650, 1.0732), which are proportional to the increasing percentages of starch (41.37, 43.51, 44.32), but inversely proportional to the diminishing percentages of sucrose (7.37, 6.15, 4.89). Or to express it differently: The specific gravity is proportional to the starch/sugar ratio. The very intimate relationship between the specific gravity and the starch/sugar ratio is at once evident from Fig. 4. Thus, the graphs (1) and (2) signifying peas

FIG. 4.



Starch/sugar ratio of the pea seeds.

Relation of specific gravity to starch/sugar ratio of the pea seeds.

planted April 20 and harvested June 11 and 12, respectively, as well as the graphs (3) and (4) indicating peas planted April 30 and picked June 18 and 19, respectively, represent almost

diagonal straight lines. In other words, the graphs go to show that as the starch/sugar ratio rises, so does the specific gravity. This is to say that the specific gravity is directly proportional to the starch/sugar ratio. Hence, like the starch/sugar ratio, *the specific gravity directly indicates the maturity or quality of peas*, i.e., a higher specific gravity indicates a poorer quality, while a lower specific gravity indicates a better quality. It may be of interest here to state that the 1934 results just discussed stand in complete agreement with the experimental data on peas secured in the season of 1935.

THE EXPERIMENTAL RESULTS ARE CORROBORATED BY FUNDAMENTAL PRINCIPLES.

The conclusions drawn from the experimental results are fully corroborated by two fundamental principles. The first, the biological principle, may be expressed as follows: Younger organisms and tissues have, as a rule, a higher water and a correspondingly lower dry matter content than older ones. Consequently, younger peas and ordinarily peas of smaller grade should naturally have a smaller dry matter content than older peas. The well-known physiological principle may be stated as follows: The first carbohydrate to be synthesized in higher plants is sugar out of which, later on, starch is formed. Hence, younger peas and ordinarily peas of smaller grade should naturally have a higher sugar and lower starch content; and conversely, older peas should naturally have a higher starch and lower content of sugar, the latter having been partly converted into starch. The analytical results given in the table show that, by and large, they stand in excellent agreement with these two principles.

On the basis of the data given in this paper the statement appears to be justified that the writer's maturity test bids fair to become of the greatest economic importance to the American pea industry, because the latter will have in the test a ready valuable means to grade the peas quickly and reliably and thus to save all of their fine qualities. In other words, thanks to the maturity test peas of superior qualities will be available for the market and for canning, with the result that vastly greater profits will be realized than was possible by any of the previous methods.

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The New Montville Turbine.—N. D. GOVE (*Electric Journal*, Vol. 34, No. 2). What promises to be a new line in steam turbines for central stations, is the installation now in preparation at the Montville plant of the Connecticut Light and Power Co. It is a large single cylinder, 3600 r.p.m. condensing turbine. The rating is 25,000 kw. maximum with normal steam conditions of 640 pounds per square inch gage, 825 deg. F. throttle temperature, 29 inches vacuum. The turbine is arranged for either three of four stage feed heating, as desired, and with either arrangement will deliver current to the switchboard at a heat rate less than 10,000 B.t.u. per kw.-hr., insuring at least a kilowatt per pound of coal. Unusual features include the elimination of all fire hazard and an oil operated transformer type throttle valve. The development of this unit offers a marked increase in the possibilities for future power extensions. In out-of-date plants it can, because of its compactness, be installed in the place formerly filled by comparatively small turbines. In more modern plants, it can, as at Montville, be placed in a location reserved for a 10,000 kw., 1800 r.p.m. unit. In new plants of moderate size systems, it can be the first of a line, increased from year to year by duplicate equipment. In larger systems it offers, in a single or multiple units, economical generation at scattered load centers.

R. H. OPPERMANN.

LAW OF SIZE DISTRIBUTION AND STATISTICAL DESCRIPTION OF PARTICULATE MATERIALS.*

BY

PAUL S. ROLLER.†

A law of size distribution has been found which relates the weight per cent., and from this the frequency, to size of particle for finely divided materials. The relationship was first induced from data obtained with a particle size air analyzer [1] on six materials, five mechanically pulverized and one a natural china clay. Since the experimental method used was one of direct separation with check by the microscope and check also in other ways, there was considerable assurance of the absolute correctness of the data, which were reproducible to about 0.5 unit of percentage by weight. After having found agreement with the air-analyzer data, it was decided to test the distribution law further by means of data obtained by other observers using different methods on a variety of materials. Some care had to be exercised in the choice of data taken from the literature since in this field of measurement there are much insufficiently considered theory and practice. Therefore, only data were considered that were obtained on the basis of Stokes' law of particle fall without any other theoretical or practical assumptions, or that were directly obtained by observation with the microscope, and that furthermore were sufficiently precise.

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[1] The apparatus and the principle on which it is based were originally described in (1) U. S. Bureau of Mines Tech. Paper No. 490, 46 pp. (1931), significant improvements in mechanical construction and mode of operation were later given in (2) *Proc. Am. Soc. Testing Materials*, **32**, II, 607–25 (1932), and in (3) *J. Am. Cer. Soc.* (in press). Most of the data referred to are discussed in detail in the latter publication.

GENERAL PROPERTIES OF THE LAW OF DISTRIBUTION.

The law of size distribution that forms the basis of this paper is written

$$y = ax^{1/2}e^{-b/x}, \tag{1}$$

where y is the weight per cent. of all material less than x microns in diameter, and a and b are constants.

Equation (1) for the mass distribution may be written as a mass frequency law as follows:

$$\frac{dy}{dx} = a\left(\frac{0.5}{x^{1/2}} + \frac{b}{x^{3/2}}\right)e^{-b/x}, \tag{2}$$

where dy/dx is the frequency in weight per cent. per micron.

Or equation (1) may be written as a number frequency law. It is first necessary to observe the relation between weight and number as follows:

$$dy = 10^{-10}\rho x^3 dz, \tag{3}$$

where z is the number of particles, ρ is the density of the material, and x, the diameter in microns, is suitably defined as by equation (17).

On substituting for dy into (2) from (3), the number frequency distribution is obtained as follows

$$\frac{dz}{dx} = 10^{10}\frac{a}{\rho}\left(\frac{0.5}{x^{7/2}} + \frac{b}{x^{9/2}}\right)e^{-b/x}. \tag{4}$$

We shall be concerned almost exclusively with the mass distribution relationship because of its greater simplicity. Number frequency distribution can of course always be converted to mass frequency distribution by means of equation (3).

A graph of equations (1) and (2) gives curves I and II, respectively, of Fig. 1. The mass equation (1) shows an inflection point, and the mass frequency equation (2) shows a corresponding maximum, at size $x = x_i$. The value of x_i may be determined analytically by differentiating equation (2) and setting the derivative equal to zero. The value of x_i so determined is

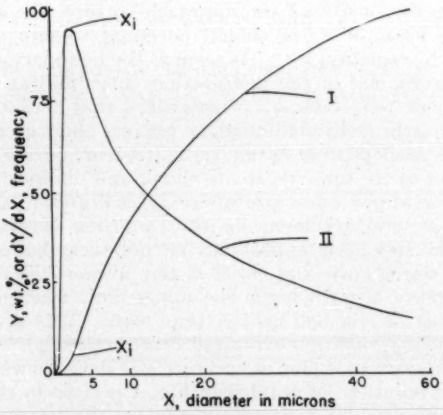
$$x_i = 0.828b. \tag{5}$$

The number frequency distribution given by equation (4) also shows a maximum, and this is found to be at

$$x_{i,\,z} = 0.228b. \tag{6}$$

The value of the particle size at the maximum in the mass or number frequency distribution, or the mode, is seen to be determined solely by the value of the constant b in the distribution equation.

FIG. 1.



Example of curve of mass distribution (I), and of corresponding mass frequency distribution (in arbitrary units) (II). Boundary conditions and form of curve agree experimentally and theoretically.

Other properties of the mass distribution law given by equation (1) are as follows:

$$y = 0 \quad \text{at} \quad x = 0, \tag{7}$$

$$\frac{dy}{dx} = 0 \quad \text{at} \quad x = 0, \tag{8}$$

$$\frac{dy}{dx} > 0 \quad \text{at} \quad y = 100. \tag{9}$$

Equations (7) to (9) give the theoretical boundary conditions. These seem to be satisfied by an experimental

plot of accurate size data such as that shown in Tables I*a* to I*e*. They appear also to be the conditions that one would expect. An attempt to interpret them on a physical basis may be made as follows: In regard to equation (7) it is a self-evident physical condition that the weight per cent. is zero at a size equal to zero. As regards (8) it may be noted that in reducing a powder, the very smallest particles, atoms and electrons, tend to recombine about as fast as formed due to the too great vapor pressure. Hence in any mechanical reduction of a material the approach to zero size should be infinitely slow, or dy/dx should be equal to zero at $x = 0$, as given by equation (8). As regards the boundary condition at the upper end of the distribution curve and at a weight per cent. of 100, it must be recognized that actual powders are often arbitrarily delimited as regards their greatest size by some such process as air separation or sieving, so that conditions at the uppermost size should not differ appreciably from those at any other size where dy/dx is greater than zero. A more general argument for the condition $(dy/dx) > 0$ at the upper size limit appears to be however that since the greatest size is finite and exists in the powder, the frequency of occurrence of particles in the upper limit which is simply dy/dx must be real and greater than zero. This agrees with the boundary condition expressed by equation (9).

An experimental plot of accurate size data shows that the inflection point, x_i, of graph I in Fig. 1 is close to the origin, and indeed may be so close, usually for the finest powders, as to nearly escape notice. The closeness of x_i to 0 is however predicted by equation (5), since b, it is observed, is usually less than 4 microns in size and for very fine powders may fall to as low as 0.02 micron.

It is unfortunately not possible to solve equation (1) explicitly for the diameter x. The best procedure for this purpose appears, then, to be a graphical one. However an approximate solution may be obtained for x large. The largest calculated value of x, x_g, corresponds to a value of 100 substituted for y. Expanding the exponential in a power series, it is found from equation (1) that

$$x_g \doteq \left(\frac{100}{a}\right)^2 \left\{1 + 2\left(\frac{a}{100}\right)^2 b\right\}. \qquad (10)$$

The error involved in this solution for x_0 is discussed later in connection with the determination of the surface area of a powder, for which case it is shown that the error is almost always negligibly small.

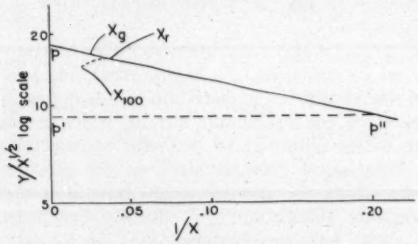
THE DISTRIBUTION CONSTANTS a AND b AND THE CHARACTERISTIC CURVE.

Evaluation of the constants a and b in equation (1) from experimental data is simple. Equation (1) may be written in the form

$$\log \frac{y}{x^{1/2}} = \log a - 2.303 \frac{b}{x}. \qquad (11)$$

By this equation, if one plots $\log y/x^{1/2}$ against $1/x$, the resulting curve is a straight line as shown in Fig. 2. This

FIG. 2.



Characteristic line corresponding to distribution of Fig. 1.

line may be called the "characteristic line" while the curve which may be obtained in general in a plot of $\log y/x^{1/2}$ against $1/x$ may be called the "characteristic curve." The intercept of the characteristic line on the $\log y/x^{1/2}$ axis is $\log a$ while the slope is equal to $-2.303b$. In Fig. 2, for example, considering the ordinate scale to be logarithmic instead of cartesian, the value of $y/x^{1/2}$ at p is equal to constant a. The value of b is given by $(2.303/p'')(pp'/10 - 1)$ where p'' is the magnitude of $1/x$ at point p'', pp' is the measured length from p to p' and $10 - 1$ is the measured length from 10 to 1 on the ordinate scale.

In any actual powder it is found that the coarsest sizes do not obey the law of distribution. Thus in Fig. 2 the dotted

portion of the characteristic curve shows the actual course of the curve of log $(y/x^{1/2})$ against $1/x$ at the coarsest sizes. It is seen that the actual values of log $y/x^{1/2}$ are smaller than the values predicted by equation (1). The way this comes about is as follows. During pulverization, one may assume that at a given size in the interior of the powder an equilibrium holds between the rate of loss of particles to the finer sizes and the rate of gain from the coarser sizes. At the coarse end of the curve this equilibrium is disturbed by the coarsest particles not being replenished at the expected rate because of the discontinuity at the upper limit of size. Hence the distribution at the coarse end is sparser than it should be, or diluted, so that the weight per cent. in this region is invariably lower than the theoretical weight per cent. Since the dotted curve of Fig. 2 shows decreasing instead of increasing values of log $y/x^{1/2}$ with increase in x it may be called "regressive."

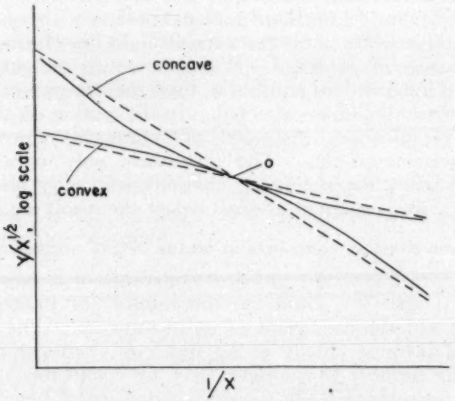
In Fig. 2 x_{100} is the experimental value of the diameter at y equal to 100 per cent. x_r is the "resolving size" or the maximum size at which the distribution law holds and which is also therefore the maximum size at which experimental values are to be obtained to evaluate constants a and b. x_g is the "statistical greatest size" in the powder, or the greatest size which the powder would have if it obeyed the distribution law throughout. x_g usually lies at a weight per cent. about half way between that for x_r and x_{100}. It may be considered roughly as the mean value of the particle sizes in the diluted region of regression extending between x_{100} and x_r.

The resolving particle size x_r usually lies at a weight per cent. above 80 per cent., but for certain very finely divided materials such as clays the weight per cent. may be considerably lower. Since the most important physical properties, such as surface area per gram, are dependent only slightly on the coarser sizes, the exact upper limit of particle size is not of much importance. In all subsequent calculations therefore we shall take the statistical greatest size, or the value of x_g, as the upper limit of particle size in the powder. The merit of this procedure is that x_g may be calculated analytically by equation (10).

TYPES OF CHARACTERISTIC CURVES.

The expected, and also the curve normally obtained, in plotting log $(y/x^{1/2})$ against $1/x$ is the straight-line characteristic with negative slope, as in Fig. 2. However at times one runs into a curve of regression, that is, as defined above, a curve of decreasing instead of increasing values of log $(y/x^{1/2})$ with decrease in $1/x$. Such regression cannot continue down to zero size, for this would mean that exponent b/x in equation (1) is positive and the weight per cent. y would therefore be infinite at zero size. Hence as x decreases the curve must

FIG. 3.



Showing the origin of concave and convex characteristics.

cease regressing at some value. Barring the possibility of experimental error, therefore, a curve of continuous regression simply signifies usually that measurements have not been made below the resolving size, x_r.

In addition to the regressive characteristic, curves may be obtained which are not straight lines but are concave or convex as the case may be but without any regression. Such curves are shown in Fig. 3. Theory and experience show that they are due to the presence of independent mixtures of substances in the powder. Consider in Fig. 3 two independent

substances whose characteristic lines (dotted) are as shown and which intersect at point *O*. Usually one substance tends to be concentrated in the coarse end of the powder and the other substance in the fine end. Therefore the actual curves must run asymptotic to the characteristic lines at their ends. Since these ends consist of one for each characteristic line each with its own slope, it is obvious that the over-all characteristic of a mixture must be concave or convex, as the case may be, and as shown in Fig. 3.

There are indications that two or more substances can partake of the same pulverization equilibrium, so that the resultant substance possesses a normal straight-line characteristic. For example, portland cement consists of three or more different ingredients yet it gives the straight line characteristic of a homogeneous material. When, however, the substances partake of independent equilibria, then the concave or convex characteristic should be expected. In the section on closeness of fit, examples are discussed of regressive, convex and concave characteristics. The latter are only occasionally observed, while the regressive characteristic may always be escaped by measurement at sizes below the resolving size.

SOLUTION FOR PHYSICAL CONSTANTS BY MEANS OF THE DISTRIBUTION LAW.

The more important physical constants of a powder are its surface area per gram, *S*, the number of particles per gram, *N*, and the coefficient of uniformity, *U*. The surface area is of interest chiefly as an index of chemical reaction rate. The number of particles may be connected with the physical property of bulk density or density of compaction. If one wishes to mix two fine powders so that their bulk density is a maximum the number of particles per gram of the one powder should be determined by the average pore size of the second powder. The coefficient of uniformity is a measure of the spread in particle size relative to the mean size and can be utilized in various ways, as for example in connection again with bulk density. In addition to the coefficient of uniformity one may consider also simply the uniformity which measures the absolute spread in particle sizes.

It is a valuable feature of the law of distribution that the surface area, the number of particles and the coefficient of

uniformity can all be expressed in terms of the fundamental distribution constants a and b. Since not more than two accurate measurements are necessary to determine these, it is seen that the important physical constants of a powder can be secured from a knowledge of the weight per cent. at only two different sizes. However at least three measurements are needed in order to estimate the accuracy of the results.

In what follows is given the derivation for S, N, and U, and also for the uniformity u.

Surface Area in Sq. Cm. per Gram, S.—In connection with the solution for S, it is first necessary to define the diameter of a particle which for nonspherical shapes obviously may be represented in a great number of ways. There is however one definition that is most appropriate for the physical quantity under discussion.

Consider a particle averaged as a rectangle of dimensions α, β and γ in microns. Then the surface area in sq. cm. per unit weight of the particle is $\frac{2}{\rho} \times 10^4\left(\frac{1}{\alpha}+\frac{1}{\beta}+\frac{1}{\gamma}\right)$, where ρ as before is the density. If the diameter of a particle is defined by the relation

$$\frac{1}{x} = \frac{1}{3}\left(\frac{1}{\alpha}+\frac{1}{\beta}+\frac{1}{\gamma}\right) \tag{12}$$

it is seen that $1/x$ is simply equal to $\rho/(6 \times 10^4)$ times the surface area per unit weight of the particle. Hence, in weight $dy/100$, the surface area, dS, is equal to

$$dS = \frac{6 \times 10^2}{\rho}\frac{dy}{x}, \tag{13}$$

with x now defined by equation (12).

Substitute for dy from (2), and let $x = (1/u)$. Then

$$S = \frac{6 \times 10^2}{\rho} a \left\{ \int_{\infty}^{0} (0.5u^{-1/2}e^{-bu} + bu^{1/2}e^{-bu})du + \int_{0}^{1/x_g} (0.5u^{-1/2}e^{-bu} + bu^{1/2}e^{-bu})du \right\}, \tag{14}$$

where x_g is the statistical upper limit of size of the powder.

The first integral in (14) is a known definite integral. The second integral may be determined to any desired degree of precision after first expanding e^{-bu} in a power series of bu. After reduction the following expression is obtained:

$$S = \frac{1.064 \times 10^3}{\rho} \frac{a}{b^{1/2}} \left\{ 1 - \sqrt{\frac{b}{\pi x_g}} \left(1 + \frac{1}{3}\frac{b}{x_g} - \frac{3}{10}\left(\frac{b}{x_g}\right)^2 + \frac{2}{21}\left(\frac{b}{x_g}\right)^3 \cdots \right) \right\}. \quad (15)$$

Since b is the value of x near the maximum of the frequency distribution (equations 5 or 6) and accordingly is small, while x_g is the statistical greatest particle size, b/x_g is usually very small; hence the series in powers of b/x_g converges rapidly. Experience shows that it results in little error to omit higher terms in the series and to substitute for x_g its approximate value from (10). One obtains in this way finally for the surface area per gram,

$$S = \frac{1.064 \times 10^3}{\rho} \frac{a}{b^{1/2}} \left(1 - 0.56 \sqrt{\frac{\left(\frac{a}{100}\right)^2 b}{1 + 2\left(\frac{a}{100}\right)^2 b}} \right). \quad (16)$$

The term in parentheses in equation (16), which corrects for the finite upper limit of particle size, as a rule differs little in practice from unity. We have examined the formal error in this term caused by substituting for x_g its approximate value in terms of a and b.

Letting $0.56 \sqrt{\frac{\left(\frac{a}{100}\right)^2 b}{1 + 2\left(\frac{a}{100}\right)^2 b}}$ be equal to ϵ, it is found that with $2(a/100)^2 b < 0.8$ the error in ϵ is less than 2 per cent. if $\epsilon < 0.25$ and less than 5 per cent. if $\epsilon < 0.5$, while if $2(a/100)^2 b < 0.4$, the corresponding errors in ϵ are less than 1 per cent. and 2 per cent. respectively. Since even the lowest values of the limits in $2(a/100)^2 b$ and ϵ that have been instanced are seldom exceeded it is almost always found to be quite permissible to use the more convenient equation (16) for S instead

of (15). A further argument in favor of the procedure of using equation (16) instead of (15) is that the distribution of the coarser sizes of a powder is not well defined for reasons discussed above and x_g itself therefore is only a mean value to begin with.

Number of Particles per Gram, N.—It is first necessary to redefine the diameter of a particle so as to make it conform to the desired quantity, N. The diameter thus calculated will be numerically different from the value given by (12) that relates to surface area, and in general as pointed out by Perrott and Kinney[4] different definitions of the diameter of non-spherical particles prevail depending on the physical or geometrical property that is of interest.

If as before the typical particle is considered as a rectangle of dimensions α, β, and γ, then the volume of the particle is $\alpha\beta\gamma$ and its weight is $\rho\alpha\beta\gamma$. If the diameter of a particle is defined then by the relation

$$x = (\alpha\beta\gamma)^{\frac{1}{3}}, \tag{17}$$

it is seen that $1/\rho x^3$ is equal to the number of particles of diameter x per gram.

The number of particles, dz, in the weight per cent. interval, dy, is given by equation (4) above with x now defined by (17). Integration of (4) is carried out in a manner quite similar to that in obtaining the surface area, S. The result for the number of particles per gram is

$$N = 10^{10}\frac{a}{\rho b^{5/2}}\left\{\frac{1}{2}\Gamma(3/2+1) + \Gamma(5/2+1) - \frac{1}{5}\left(\frac{b}{x_g}\right)^{5/2}\left(1 + 0.71\frac{b}{x_g} + \cdots\right)\right\}. \tag{18}$$

The gamma functions in (18) evaluate to 3.99. The terms in $(b/x_g)^{5/2}$ and higher are so small that they may be safely neglected, though if it were desired one could substitute for x_g its approximate value from (10) as was done in evaluating S. The final result for the number of particles per gram is then

$$N = \frac{3.99 \times 10^{10}}{\rho}\frac{a}{b^{5/2}}. \tag{19}$$

[4] G. St. J. Perrott and S. P. Kinney, *J. Am. Cer. Soc.*, 6, 417–39 (1923).

Uniformity and Coefficient of Uniformity.—The uniformity, u, at size x may be defined by the derivative

$$u_x = \frac{1}{100}\frac{dy}{dx}. \tag{20}$$

This expression gives the ratio of the spread in weight per cent. to the spread in particle size. In comparing the uniformity of the distribution of a first and second point, the uniformity is greater at the first point if the change in weight for a given spread in particle size is greater at that point. This is what would be expected and what equation (20) shows.

The uniformity, u, of the powder as a whole is found by averaging u_x between the limits x_2 and x_1, thus

$$u = \frac{\int_{x_1}^{x_2} u_x dx}{x_2 - x_1} = \frac{1}{100}\frac{\int_{y_1}^{y_2} dy}{x_2 - x_1}. \tag{21}$$

According to the method of quartiles in statistics[5] the dispersion is given by $(x_{75} - x_{25})/2$, and the uniformity is given by the reciprocal of this expression, where x_{75} and x_{25} are the diameters at 75 and 25 weight per cent. respectively. In order to make u in (21) conform to the results obtained by the method of quartiles, the limits x_2 and x_1 will be taken as x_{75} and x_{25} so that the uniformity is

$$u = \frac{0.5}{x_{75} - x_{25}}. \tag{22}$$

The coefficient of uniformity is a quantity of probably greater significance for size analysis than the uniformity itself as it alone is appropriate for comparing the distributions of powders of different mean size. The coefficient of uniformity is the uniformity relative to the mean value of the quantities involved. In accordance with this conception the coefficient of uniformity U_x at a point x in the distribution is

$$U_x = \frac{dy/y}{dx/x} = \frac{d \log y}{d \log x}. \tag{23}$$

[5] G. U. Yule, "Introduction to the Theory of Statistics," J. B. Lippincott & Co. (1934).

On substituting for y from equation (1), one obtains

$$U_x = 0.50 + \frac{b}{x}. \tag{23a}$$

The coefficient of uniformity for the whole powder is obtained by averaging U_x. The average is most simply taken over y, thus

$$U = 0.50 + \frac{\int \frac{b}{x} dy}{100}. \tag{24}$$

$\int (dy/x)$ in (24) has already been evaluated in obtaining an expression for the surface area, S. By comparing equations (13), (15), (16) and (24) it is found that the coefficient of uniformity, U is given by

$$U = 0.50 + 0.0177ab^{1/2}\left\{1 - \sqrt{\frac{b}{\pi x_g}}\left(1 + \frac{1}{3}\frac{b}{x_g} - \frac{3}{10}\left(\frac{b}{x_g}\right)^2 + \frac{2}{21}\left(\frac{b}{x_g}\right)^3 \cdots\right)\right\} \tag{25}$$

and, with x_g substituted by its approximate value in terms of a and b, the result obtained for U is finally

$$U = 0.50 + 0.0177ab^{1/2} \times \left(1 - 0.56\sqrt{\frac{\left(\frac{a}{100}\right)^2 b}{1 + 2\left(\frac{a}{100}\right)^2 b}}\right). \tag{26}$$

Equation (26), like the corresponding equation (16) for the surface area per gram in its relation to (15), is sufficiently accurate to be used almost invariably in place of the more extended but less convenient equation (25).

By the method of quartiles the coefficient of uniformity, U, is simply

$$U_q = \frac{2x_{50}}{x_{75} - x_{25}}. \tag{27}$$

It will be seen in the section on comparison of integral and increment values that the coefficient of uniformity given by

the quartile equation (27) and by the statistical equation (26) is in considerable agreement.

CLOSENESS OF FIT.

The law of mass distribution expressed by equation (1) was tested against data obtained by various methods and for a variety of materials, both mechanically pulverized and produced by physical and chemical processes. As noted in the introduction only those data could be considered the methods for which were unambiguous and the procedure for which was accurate. The materials ranged from a comparatively coarse commercial feldspar powder to an extremely fine ball clay, and included ceramic powders, paint pigments hydrated limes, soils and clays. Each class of materials will be separately discussed.

The method of determining the fit was to plot log $y/x^{1/2}$ against $1/x$ as already described and draw the best straight line through the experimental points. The values of the weight per cent. y were then computed from the characteristic line at different values of the diameter x, and the calculated values compared with the experimental ones. Points in the regressive region where $y/x^{1/2}$ begins to decrease instead of increase were neglected.

The results are shown in Tables 1 to 5, which give the observed weight per cent. at different sizes, the difference between the observed and calculated values, and in the last column the probable error of a single determination, r. The probable error was determined by the formulæ given by Bond [6] for a curve with two constants, namely,

$$r = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n-2}}. \qquad (28)$$

In this equation v is the deviation between the observed and calculated values, and n is the number of points. It will be noted that, as would be expected, data for at least three points are necessary for estimating the probable error.

In Table I*a* are shown the data for ceramic materials and for two cements as determined by a particle size air analyzer [1]

[6] W. N. Bond, Probability and Random Errors, Edw. Arnold (1935).

CLOSENESS OF FIT. OBSERVED VALUES OF THE WEIGHT PER CENT. AT DIFFERENT SIZES AND THE DIFFERENCE BETWEEN THE OBSERVED AND CALCULATED VALUES.

r = Probable Error of a Single Determination.

TABLE Ia.

Ceramic Materials and Cements. Data of Present Author,[1] by the Method of Fractionation with a Particle Size Air Analyzer.

Diameter, microns	5	10	20	40	r
Feldspar	14.1	27.5	47.3	77.3	
Calculated-Observed	0.0	+1.1	+1.3	−2.0	1.3
Flint	15.9	32.6	54.3	81.7	
Calculated-Observed	0.0	−0.7	−0.5	+1.2	0.7
Cement Nw	19.4	34.8	55.0	80.0	
Calculated-Observed	+0.2	−0.3	−0.3	+1.6	0.8
Cement Sa	21.0	40.8	65.9	93.4	
Calculated-Observed	0.0	−0.4	+0.5	—	0.4
China Clay C	28.5	46.6	71.1	97.1	
Calculated-Observed	0.0	0.0	0.0	—	0.0
Talc	34.7	50.3	71.7	95.1	
Calculated-Observed	0.0	0.0	0.0	—	0.0
Average					0.5

referred to above. The deviation of the experimental from the calculated values of the weight per cent. are seen to be random. The probable error ranges from 0.0 to 1.3 units of percentage, and averages for all the materials, 0.5, which is equal to or better than the precision of the measurements.

Results for pigment materials are shown in Table I*b*. The data were obtained by Dunn and Shaw [7] by means of

TABLE Ib.

Paint Pigments. Data of Dunn and Shaw [7] by the Method of Microscope Projection.

Diameter, microns	0.5	0.75	1.0	1.5	2.0	3.0	4.0	6.0	8.0	12.0	16.0			r
Red Lead	0.3	1.2	3.0	7.3	13.6	24.1	38.7	62.5	75.0	89.0	94.8			
Calc.-Obs.	−0.1	0.0	0.0	+1.4	+0.9	+2.7	−0.7	−5.4	−1.4	—	—			1.6
Litharge	2.2	8.3	15.7	35.6	56.8	86.8	98.0	99.3	100					
Calc.-Obs.	0.0	−0.1	+0.8	0.0	−2.4	+1.4	—	—	—					1.0
Diameter, microns	0.58	1.16	1.73	2.31	3.47	4.63	6.94	9.25	13.9	18.5	27.7	37.0	55.5	r
Silica	1.0	6.40	12.8	18.7	25.8	32.0	39.3	47.0	58.1	72.4	88.3	96.3	99.6	
Calc.-Obs.	+0.5	+0.2	−1.3	−2.6	−2.2	−1.9	+0.8	+2.0	+3.3	+1.6	—	—	—	1.4
Average														1.3

[7] E. J. Dunn, Jr., and John Shaw, *Proc. Am. Soc. Testing Materials*, 33, II, 629–703 (1933).

microscope projection,[8] and involved estimating the size, counting, and summing the particles. Several thousand particles were counted for each material. The silica was dry-ground in a laboratory jar mill, and the red lead was dry-ground in a Stroud mill and air-floated.* The litharge was made by sublimation. The wave-like fit for red lead and silica, in other words the relatively small number of changes in sign for the deviations, is possibly connected with a small systematic error involved in changing from one size fraction and microscope objective to another in making the complete analysis of these materials. The deviations for litharge are seen to be random. The probable error is 1.4, 1.6 and 1.0 units of percentage, respectively, with an average of 1.3.

The data of Dunn and Shaw include also a precipitated basic lead chromate. This material shows a concave characteristic typical of a mixture of independent components. The basic lead chromate was made from a mixture of lead sulphate, litharge and zinc oxide at pH of 10 or 11, and might be a mixture of lead chromate and zinc chromate.* The concave characteristic for this material is therefore not unexpected.

In Table Ic are given data on hydrated limes obtained by Bishop.[9] The method of measurement was sedimentation using an automatic weighing apparatus. The weight per cent.

TABLE Ic.

Hydrated Limes. Data of Bishop[9] by the Method of Sedimentation with Weighing.

Diameter, microns.....	3	5	10	20	30	40	r
Hydrated Lime, 4....	10	30	75	87	91		
Calc.-Obs.....	0	0	+1	−	−		1
Hydrated Lime, 1....	20	45	90	98			
Calc.-Obs.....	0	−3	+2	−			2
Hydrated Lime, 5....	19	45	80	91			
Calc.-Obs.....	+1	−3	+3	−			3
Hydrated Lime, 3....	6	20	70	92	97		
Calc.-Obs.....	0	+2	0	−	−		1
Hydrated Lime, 2....	8	32	73	94			
Calc.-Obs.....	+1	−4	+4	−			4
Average.....							2

[8] E. J. Dunn, Jr., "Ind. and Eng. Chem.," Anal. Ed. 2, 59–62 (1930).

* Private communication from Mr. Dunn.

[9] Dana L. Bishop, Bu. of Stds. J. Research (Research Paper 642), 12, 173–83 (1934).

is given only to the nearest unit although the apparent precision warrants a more complete statement. In view of the method of presentation the deviations are computed also only to the nearest unit. The probable error ranges from 1 to 4 units of percentage with an average of 2.

Bishop's data included also values for four hydrated dolomitic limes. These all showed a not unexpected convex characteristic typical of a mixture, and so are omitted from consideration.

Data for two soils are given in Table I*d*. These were secured by Puri [10] by sedimentation methods using pipette

TABLE I*d*.

Soils. Data of Puri [10] by the Method of Sedimentation with Pipette Withdrawals.

Diameter, microns.	2	4	6	8	10	20	40	60	80	r
Soil P.C. 1.....	11.3	16.0	23.6	29.0	34.6	58.1	86.3	97.6		
Calc.-Obs.....	−4.7	+0.1	+0.2	+1.0	+1.9	−2.0	−1.5	—		1.7
Soil P.C. 34.....	11.3	18.8	25.0	29.6	35.0	54.2	74.6	81.4		
Calc.-Obs.....	−1.4	+0.4	0.0	+0.9	0.0	−1.4	+1.3	—		0.9
Average.....										1.3

and hydrometer; only the former method is considered. The deviations are random; the probable errors are 1.7 and 0.9 units of percentage, averaging 1.3, which is approximately the precision of the data.

Puri also included values for eleven other soils, but these showed a regressive characteristic. Purely as speculation, this might be due to continuous uncompensated decomposition of the soils, whereas soils P.C. 1 and P.C. 34 which give a straight-line characteristic may have been laid down without subsequent continued erosion. It is probable by comparison for example with the clays next to be discussed that the regressive characteristics would have changed to normal straight lines if measurements had been made at sizes less than 2 microns, that is to say below the resolving size.

In Table I*e* are given some remarkable data obtained by Vinther and Lasson [11] for twelve kaolins and two ball clays.†

[10] Amar Nath Puri, *Soil Sci.*, 33, 241–8 (1932).

[11] E. H. Vinther and M. L. Lasson, *Ber. deutsche Keram. Gesellschaft*, 14, 259–70 (1933).

† Description of the kaolins and ball clays corresponding to the numbers of Table 5, as given by the authors, is as follows: for the kaolins, (1) Hirschauer

TABLE Ie.

Kaolins and Clays. Data of Vinther and Lasson [11] by the Method of Sedimentation with Pipette Withdrawals.

Diameter, microns	0.13	0.22	0.36	0.56	0.80	1.15	2.15	4.08	5.83	8.70	12.3	19.4	r
Kaolin 1	1.4	2.5	5.3	11.9	17.4	24.0	35.1	52.4	62.3	71.2	77.9	89.3	
Calc.-Obs.	−0.8	+0.1	+0.7	−0.5	−0.7	−0.5	+1.4	+1.6	—	—	—	—	0.7
Kaolin 2	2.6	7.2	17.3	25.2	33.2	40.2	52.7	65.7	77.6	87.7	93.6	97.7	
Calc.-Obs.	−0.2	+0.1	−2.3	−0.8	+1.0	—	—	—	—	—	—	—	1.0
Kaolin 3	3.5	7.6	13.4	20.1	25.9	31.3	45.7	67.9	76.7	87.0	90.7	94.6	
Calc.-Obs.	−0.2	+0.2	−0.3	−0.7	0.0	+1.7	+2.5	+1.1	—	—	—	—	0.9
Kaolin 4	1.8	4.0	12.5	24.1	31.3	37.7	48.6	63.0	74.2	86.0	92.4	96.6	
Calc.-Obs.	−0.5	+1.4	+0.1	−1.5	+1.8	—	—	—	—	—	—	—	1.1
Kaolin 5	2.0	7.4	13.9	37.3	47.6	55.2	73.0	87.3	94.3	96.8	98.7	98.7	
Calc.-Obs.	−0.4	−0.2	+4.1	−3.7	+2.4	—	—	—	—	—	—	—	2.3
Kaolin 6	2.3	6.3	16.7	37.8	49.7	58.9	71.6	80.8	86.8	90.6	94.1	96.3	
Calc.-Obs.	−0.7	+0.9	+1.3	−4.2	+0.3	—	—	—	—	—	—	—	1.8
Kaolin 7	4.2	11.6	22.2	33.4	41.7	49.4	62.0	73.7	82.0	88.5	92.5	95.2	
Calc.-Obs.	0.0	−0.4	−1.3	−0.9	+2.0	—	—	—	—	—	—	—	1.0
Kaolin 8	5.1	15.6	27.3	37.7	46.6	50.5	62.6	78.0	85.4	94.0	95.8	97.6	
Calc.-Obs.	+1.5	−1.0	−2.2	−1.0	+2.4	—	—	—	—	—	—	—	1.5
Kaolin 9	8.7	14.7	23.5	31.6	39.1	46.1	61.4	77.6	86.0	90.8	93.6	96.7	
Calc.-Obs.	0.0	+0.7	−0.2	0.0	+1.0	—	—	—	—	—	—	—	0.5
Kaolin 10	7.0	16.3	29.0	41.4	49.8	60.1	75.6	89.8	96.0	98.8	98.8	99.7	
Calc.-Obs.	+0.4	0.0	−1.7	−1.4	+2.7	—	—	—	—	—	—	—	1.4
Kaolin 11	9.7	16.6	23.5	33.4	42.1	50.8	64.5	77.6	83.3	88.1	91.6	94.6	
Calc.-Obs.	0.0	−0.4	+0.5	−0.9	−1.1	0.0	—	—	—	—	—	—	0.5
Kaolin 12	9.3	22.5	34.7	48.0	54.5	61.2	72.7	79.5	86.0	89.2	93.2	95.3	
Calc.-Obs.	+0.1	−1.9	0.0	+2.5	—	—	—	—	—	—	—	—	1.5
Ball Clay 1	29.3	45.9	59.8	70.4	72.1	73.2	75.2	76.3	78.4	79.4	81.5	84.2	
Calc.-Obs.	+0.6	−1.5	+2.0	—	—	—	—	—	—	—	—	—	1.7
Ball Clay 2	53.4	74.6	85.6	88.7	91.9	93.0	94.7	94.6	96.0	95.7	95.7	95.7	
Calc.-Obs.	(0.0)	(0.0)	—	—	—	—	—	—	—	—	—	—	—
Average													1.2

These data include measurement of sizes down to 0.13 micron. The pipette method was used. The deviations are plus and minus at random. For the kaolins the probable error of a single measurement ranges from 0.5 to 2.3 units of percentage and averages for all of the kaolins 1.2 units. This result may be considered excellent considering the unusually small sizes measured. The ball clays are exceedingly fine and though measurements were made on eight, only for ball clay 1 are there more than two points below the resolving size. The probable error here is 1.7. Ball clay 2 is the finest of those measured and is included not as a test of the goodness of fit but merely because of general interest in its

(Gebr. Dorfner), (2) china clay (Wm. Adolph & Co., Ltd.), (3) Kemmlitzer (Seok), (4) china clay (Varcoe China Clay, Ltd.), (5) Kaolin d'Arvor, Lorient, (6) Russian (Gloukov), (7) china clay (English China Clay, Ltd.), (8) Bornholmer, (9) Kemmlitzer (Wolf), (10) Zettlitzer (Zettlitzer Kaolin Werke), (11) Seilitzer (Deutsche Feldspat u. Kaolin Werke), (12) Nordböhmischer (Grohlmann); for the ball clays, (1) Wildsteiner Blauton S (Werner & Co.), (2) Bindeton (origin unknown) (W. Priem).

physical constants which were obtained on the basis of the two finest sizes only.

The probable error of a single determination, averaged for all the data obtained by each observer, ranges from 0.5 to 2 units of percentage, with an unweighted grand mean of 1.3 units of percentage by weight. This we believe to be approximately the mean precision of all the measurements. It might be remarked that the closeness of fit would no doubt have been better than 1.3 if instead of graphical determination of the distribution constants the method of least squares had been used.

PHYSICAL CONSTANTS OF POWDERS STUDIED.

The constants of surface area per gram, S, number of particles per gram, N, and coefficient of uniformity, U, have been determined for the powders of Tables I*a* to I*e* by means of equations (16), (19), and (26) respectively. However for the litharge of Table II*b* with an unusually high value for $2(a/100)^2b$ of 2.74, S and U were determined by equations (15) and (25) containing x_g which in turn was determined from the characteristic line.

Tables II*a* to II*e* correspond to Tables I*a* to I*e*. Each table pertains to one class of materials and shows for each of the powders the values of the following constants, density ρ, distribution constants a and b, surface area per gram, S, number of particles per gram, N, and coefficient of uniformity, U. In any one table the powders have been arranged in the order of increasing surface area.

Considering the ceramic materials and cements of Table II*a*, S ranges from 2420 sq. cm./gm. for feldspar to 11,900 for talc. The English china clay seems unusually coarse, but this material was checked by an accurate test of settling with repeated decantation.[3] N increases with increase in S except for the cements, where brand *Nw* has a larger number of particles than brand *Sa* though its surface area is smaller, *Nw* and *Sa* were both laboratory ground under the same conditions, but *Nw* shows an appreciably lower coefficient of uniformity than *Sa*. Being less uniform, the spread of particles sizes is greater for *Nw*, giving it a relatively large number of the finest particles, so that while its surface area

PHYSICAL CONSTANTS OF MATERIALS, AS DETERMINED BY THE LAW OF SIZE DISTRIBUTION FROM THE DATA OF TABLES Ia TO Ie.

ρ = Density; a and b are Distribution Constants; S = Surface Area in Sq. Cm. per Gram; N = Number of Particles per Gram; U = Coefficient of Uniformity.

TABLE II*a*.

Ceramic Materials and Cements.

	ρ	a	b	S	N	U
Feldspar	2.60	13.0	3.61	2,420	0.81×10^{10}	0.88
Flint	2.65	14.3	3.49	2,640	0.95	.91
Cement *Nw*	3.10	13.6	2.44	2,650	1.88	.83
Cement *Sa*	3.10	17.3	3.06	2,860	1.34	.95
China Clay *C*	2.60	17.0	1.45	5,160	10.3	.82
Talc	2.90	16.2	0.227	11,900	907	.63

is less than for cement *Sa* the number of particles is actually greater. We are inclined to attribute the lower uniformity of cement *Nw* to its being softer than *Sa*. The talc is very soft and is seen to have a very low coefficient of uniformity.

In Table II*b* the silica has the largest surface area per gram

TABLE II*b*.

Paint Pigments.

	ρ	a	b	S	N	U
Red Lead	9.10	35	2.46	1,960	1.6×10^{10}	1.23
Litharge	9.50	90	1.69	4,430	10.2	1.65
Silica	2.65	18.4	1.30	5,760	14.4	0.83

but on a basis of surface area per cc. of powder it would have a much smaller area than the lead pigments. The unusually high coefficient of uniformity of 1.65 for the sublimed litharge is to be noted.

The hydrated limes of Table II*c* have surface areas ranging

TABLE II*c*.

Hydrated Limes.

	ρ	a	b	S	N	U
Hydrated Lime 4	2.20	50	0.82	21,000	1.5×10^{12}	1.13
" " 1	"	45	0.62	22,700	2.7	1.01
" " 5	"	48	0.67	22,900	2.4	1.06
" " 3	"	37	0.35	26,600	9.3	0.84
" " 2	"	44	0.40	27,600	7.4	0.92

from 21,000 to 28,000 sq. cm./gm. The number of particles is correspondingly high. The coefficient of uniformity varies from 0.84 to 1.13, and seems to be better related to the number of particles than does the surface area.

Judging from the magnitude of their surface area, the soils of Table II*d* are of the loam type. They are much more similar in surface area than in number of particles.

TABLE II*d*.

Soils.

	ρ	a	b	S	N	U
Soil P.C. 1	2.60	14.1	2.24	3,420	2.9×10^{10}	0.83
" P.C. 34	"	12.5	1.16	4,400	13.3	0.72

The kaolins and ball clays of Table II*e* are the finest materials encountered in this study. S varies widely for the kaolins, from 18,000 to 75,000. N varies even more widely and shows but little relation to S. The uniformity is sur-

TABLE II*e*.

Kaolins and Ball Clays.

	ρ	a	b	S	N	U
Kaolin 1	2.60	30	0.37	18,000	5.5×10^{12}	0.79
2	"	54	0.35	31,300	11.8	0.97
3	"	36	0.18	31,800	40.8	0.75
4	"	57	0.30	35,500	17.7	0.96
5	"	92	0.40	44,400	14.1	1.40
6	"	92	0.40	44,400	14.1	1.40
7	"	64	0.22	46,700	40.9	0.95
8	"	68	0.17	56,500	84.0	0.93
9	"	50	0.095	60,300	276	0.75
10	"	72	0.16	61,400	103	0.94
11	"	50	0.081	66,000	412	0.73
12	"	91	0.16	75,200	132	1.03
Clay 1	"	115	.042	201,000	4,970	0.86
2	"	180	.026	386,000	25,600	0.94

prisingly high for clays 5 and 6, U being 1.40 for each of these materials. The lowest uniformity is shown by kaolin 11 with U equal to 0.73. This kaolin also has by far the largest number of particles, with N equal to 412×10^{12}.

Between the finest kaolin and the coarsest clay of Table IIe, ball clay 1, there is a big gap in surface area of 126,000 sq. cm./gm. The finest clay, ball clay 2, has the very large surface area of 386,000 sq. cm./gm. The coefficient of uniformity of the ball clays is equal to about the average for the kaolins.

COMPARISON OF INCREMENT AND INTEGRAL VALUES OF THE PHYSICAL CONSTANTS.

It is rather the custom when considering size data such as those presented in Table I*a* to calculate a surface area per gram, $S_{inc.}$, by the relation

$$S_{inc.} = \frac{6 \times 10^2}{\rho} \sum \frac{\Delta y}{x_m}. \qquad (29)$$

In equation (29) Δy is the weight per cent. contained in the fraction of mean particle size x_m.

Since the surface area given by equation (29) is the sum of the increments of mean surface area of the individual fractions, $S_{inc.}$ may be called the increment value of the surface area. Obviously $S_{inc.}$ will vary with the magnitude and the number of fractions. Indeed there is an absolute upper limit to the increment value which occurs when the particles composing the powder fall all below the nominal upper size of the finest fraction. This upper limit is evidently purely fictitious. For a series of fractions such as that shown in Table I*a*, beginning with the fraction 0–5 microns, the upper limit of $S_{inc.}$ would be

$$\frac{6 \times 10^2}{\rho} \times \frac{10^2}{2.5} \quad \text{or} \quad \frac{2.4}{\rho} \times 10^4.$$

If the beginning fraction is 0–10 microns, the upper limit of $S_{inc.}$ will be half this value or $(1.2/\rho) \times 10^4$. From this observation it may be concluded that $S_{inc.}$ will usually be smaller and in many cases very much smaller, than the integral true value of the surface area, S.

However, it may be remarked that it is possible for $S_{inc.}$ actually to be greater than S. For example comparing a 0–5 micron fraction with the equivalent two fractions 0–2.5 microns and 2.5–5.0 microns, a simple calculation shows that.

with the same total weight, $S_{inc.}$ of the two fractions will be actually less than $S_{inc.}$ of the 0–5 micron fraction if the amount of material in the 0–2.5 micron fraction is less than 25 per cent. of the whole. This situation would correspond to a comparatively coarse powder, and we might expect that for such powders $S_{inc.}$ will be about equal to S.

A comparison of the increment and integral values of the surface area is made in Table III for the materials of Table I*a*.

TABLE III.

Comparison of Integral with Increment Values of Surface Area, Number of Particles, and of Integral with Quartile Values of the Coefficient of Uniformity. Powders are Those of Table Ia.

Material	S	$S_{inc.}$	$N \times 10^{-10}$	$N_{inc.} \times 10^{-10}$	U	U_q	$U_q - U$
Feldspar	2,420	2,340	0.81	0.37	0.88	1.27	0.39
Flint	2,640	2,570	0.95	.40	.91	1.39	.48
Cement *Nw*	2,650	2,410	1.88	.41	.83	1.23	.40
Cement *Sa*	2,860	2,680	1.54	.45	.95	1.42	.47
China Clay *C*	5,160	3,780	10.3	.72	.82	1.27	.45
Talc	11,900	3,780	907	.79	.63	1.07	.44

It is seen that S taken from Table II*a* is greater than $S_{inc.}$ in all cases. The difference is small for the first four coarser materials but is very large for the finer clay and the talc. If the finest fraction had been 0–10 microns instead of 0–5 microns, $S_{inc.}$ even for the first four coarsest materials would have been much too low, in fact, only about 75 per cent. of the true integral values of the surface area.

An increment value of the number of particles per gram might also be calculated as follows:

$$N_{inc.} = \frac{10^{10}}{\rho} \sum \frac{\Delta y}{x_m^3}. \qquad (30)$$

Comparison of $N_{inc.}$ for the powders of Table I*a* with the integral, true values of N taken from Table II*a* is made in Table III. As would be expected $N_{inc.}$ is very much less than N, and especially so for the finest materials.

The last comparison of Table III is of the coefficient of uniformity as given by the method of quartiles (equation (27)) and as given by the distribution law (equation (26)). The

difference $U_q - U$ is shown in the last column. If U_q and U both represented the uniformity in the same way this difference would be constant. Actually the difference averages 0.44 with a maximum deviation of 0.05 and an average deviation of $\pm$ 0.03. Since these deviations are small compared to the maximum spread in U which is 0.95 minus 0.63, or 0.32, it is considered that the coefficients of uniformity as given by the method of quartiles and as given by the distribution law agree satisfactorily.

SUMMARY.

A law of size distribution has been discovered which relates the weight per cent., and from this the frequency, to size of particle. This law satisfies the boundary conditions and the functional form of experimentally observed distributions. Only two constants are involved which are easily determined on the basis of a linear functional relationship. The straight line obtained from this relationship is called the characteristic line.

In addition to the normal straight line characteristic, characteristics are occasionally obtained which are termed regressive, and concave or convex. A regressive characteristic signifies an uncompensated, or non-equilibrium, reduction in the coarse range of sizes. In general it passes into a normal characteristic when measurements are made at sizes sufficiently fine. A convex or concave characteristic signifies the presence of a mixture of independent components in the material. It appears that the grinding together of two or more substances can result in a powder that obeys the normal law of distribution. This is attributed to the substances partaking of the same equilibrium.

The distribution law has been found to hold for materials that have been ground mechanically or reduced by physical or chemical means. The substances that have been tested include ceramic powders, cements, paint pigments, hydrated limes, soils, kaolins and clays. The closeness of fit has been tested and found to correspond to the probable precision of the measurements.

The following important physical constants of a powder can be determined in terms of the two distribution constants:

the surface area per gram, the number of particles per gram, and the coefficient of uniformity. The various materials studied have been compared on the basis of the values for these constants. The physical constants as determined from the distribution law are integral, true values and are to be sharply differentiated from the increment values, which are customarily calculated and with which they have been compared in this study.

The advantages of applying the distribution law to experimental observations are several, as follows. The size distribution of the material is determined from two accurate values of the weight per cent. at sizes below the resolving size as defined above. When three or more values are present, the law may serve as a measure of the accuracy of the data. Individual errors can be ironed out. Measurement of the very smallest particles, which are usually the most difficult to handle, need not be made. A strongly regressive, or concave or convex characteristic, draws attention to singularity of the material, assuming of course that the unusual characteristic is not due to errors of technique or observation which must always be guarded against in this field of measurement. Finally, integral, true values of surface area, number of particles, and coefficient of uniformity are readily obtained in terms of the two fundamental distribution constants.

World's Largest Telescope Mounting An Outstanding Welded Structure.—(*Iron Age*, Vol. 139, No. 7.) According to C. H. JENNINGS, who is in charge of welding research at the Westinghouse laboratories, the mounting for the optical system of the Mt. Palomar telescope may well be regarded as the outstanding welded structure of the past year. It is remarkable not only because of its size but also because of the accuracy with which it must be fabricated and machined. The permissible error in sighting must not be greater than the angle formed by two lines three miles long subtending an arc equivalent to the thickness of a 25 cent piece. Although the complete telescope mounting will weigh more than 1,000,000 lbs. it must be constructed so that it can be controlled and turned smoothly in order that it may be sighted and held with absolute accuracy on any desired object. Because of the accuracy and smoothness required, welded construction was adopted, thereby making possible large savings in weight without loss in rigidity. The telescope mounting is composed essentially of two units, the tube and the yoke in which the tube swings on a set of flexible gimbals. All sections of the weld fabricated mounting are to be carefully strain-annealed in specially constructed furnaces to completely relieve all welding stresses. This procedure is essential to insure that the structure will remain absolutely accurate throughout its entire service life.

R. H. O.

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BENJAMIN FRANKLIN'S DISSERTATIONS RELATING TO GEOLOGIC PHENOMENA.

BY

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Franklin's distinction as a scientist was mainly based upon his researches and experiments in electricity, but his active philosophical mind was ever fully interested with other natural phenomena as well as in the observations and deductions of his contemporaries and those of earlier times.

One of his first publications having to do with earthquakes appeared in the *Pennsylvania Gazette* of December 15, 1737. Although the observations and comments in this article appear to have been largely compiled from other authors, it nevertheless shows how keenly he was alive to all scientific and philosophical discussion, and it is of interest to note that some of these observations of Franklin are in accord with our modern concepts and knowledge. Thus, for instance, earthquakes were then associated with subterranean adjustments, settlings of rock masses and strata, sometimes if not rather frequently accompanied by the exudation of fire and sulphurous gasses then assumed to be affiliated or derived from pyrites, the common sulphide of iron. Furthermore thunder and lightning were supposed to be necessarily associated with such eruptions or at least were related phenomena. This last postulate, we now are aware, although often connected with volcanic eruptions has probably nothing whatever to do with the internal activities of the eruptive material but is caused by atmospheric disturbances due to the eruption.

Earthquakes it is now well known are not usually associated with volcanic disturbances, although they are more common in volcanic areas, but are caused by strains, stresses and adjustments of the earth's outside shell or crust which, as will be later explained, is a brittle, more or less rigid framework in constant movement within itself, the causes of

which are only vaguely understood. The fact that there are more seismic disturbances in volcanic countries than elsewhere appears to have been noted by Franklin.

In his dissertations on the subject he mentions Aristotle and Pliny among the classic writers and refers to Agricola, a famous writer on mining geology of the sixteenth century, whose great book on that subject, "De Re Metallica" (first edition published 1556), was translated from Latin in 1912 by Herbert and Lou Henry Hoover (former President and Mrs. Hoover).[1] It cannot be said there is much of original observation or personal knowledge in this and other of Franklin's dissertations regarding geology; he does however appear to have had some glimmerings or inkling of what modern geologists term Isostacy or the general equilibrium of the earth's crust supposed to be maintained by the yielding and flow of the plastic rock material beneath the surface under gravitative stress.

In connection with earthquakes Franklin observes in a letter to John Pringle dated Craven Street (London), 6th January, 1758:

> Had the different strata of clay, gravel, marble, coals, limestone, sands, minerals, etc, continued to lie level, one under the other as they may be supposed to have done before these convulsions, we should have had only a few of the uppermost of the strata, the others lying too deep or too difficult to come at; but the shell of the earth being broke and fragments thrown into this oblique position, the disjointed ends of a great number of different kinds are brought up to day, and a great variety of useful materials put into our power, which would otherwise have remained eternally concealed from us, so that what has been usually looked upon as a *ruin* suffered by this part of the universe, was, in reality only a preparation or means of rendering the earth more fit for use, more capable of being to mankind a convenient and comfortable habitation.

The practical character of Franklin's mind is exhibited in this and substantially all his writings; it never deserts him.

In a letter to Abbé Soulavie dated Passy (France), 22d April, 1782, and later read at the meeting of the American Philosophical Society, November 21, 1788, Franklin observes:

[1] There are four copies of this great book in the Library of the Franklin Institute, two of which are in Latin, one in German and the Hoover translation. "For 180 years this work was not superseded as a text-book and guide to miners and metallurgists, for until Schluter's great work on metallurgy in 1738 it had no equal." (See Hoover, p. ii.)

I did not find coal mines under the calcareous rock in Derbyshire . . . and part of the high country of Derby being probably as much above the level of the sea, as the coal mines of Whitehaven were below it, seemed proof that there had been a great *bouleversement* in the surface of the island, some part of it having been depressed under the sea, and other parts, which had been under it, being raised above it. Such changes in the superficial parts of the globe seemed to me unlikely to happen, if the earth were solid to the center. I therefore imagined the internal parts might be a fluid more dense and of greater specific gravity than any of the solids we are acquainted with, which might therefore swim in or upon that fluid. Thus the surface of the globe would be a shell, capable of being broken and disordered by violent movements of the fluid on which it rested.

From this point Franklin branches off into observations upon the compression of air in connection with the above, quite fantastic and of no present interest. He nevertheless reached a theory or hypothesis largely accepted by modern geologists and geo-physicists regarding the plastic interior of the earth. It seems unlikely this concept was original with Franklin rather than a notion derived from others. It is however today one of the most radical and startling hypotheses yet advanced by modern geologists although not yet universally accepted. It is of such great interest and contains so many elements of probability I will venture to outline it in as few and simple words as possible.

If one examines the opposite coasts of the South Atlantic Ocean the similarity of the shapes of the coast-lines of Brazil and Africa will be noted. The great right-angled bend of the Brazilian coast at Cape San Roque finds an almost exact counterpart in the re-entrant angle of the African coast near the Cameroons. Also south of these corresponding points every projection on the Brazilian side corresponds to a similarly shaped bay on the African and conversely each indentation on the Brazilian coast has a complementary protuberance on the African. This conception is known as the displacement of continents or Wegenerian hypothesis and is based on the assumption of great horizontal drifting movements of the continental blocks in the course of geological time and presumably continuing today. The thesis is postulated on a fluid or semi-plastic viscous interior upon which these vast sections of the earth's crust float and drift like floating icebergs farther and farther apart. According to Wegener's conception millions of years ago the South Ameri-

can continental plateau lay directly adjoining the African plateau, forming one great connected mass. In Cretaceous time it split into two parts and drifted apart.[2]

I believe we can obtain a better understanding of Franklin's philosophy and scientific thinking if one briefly reviews the philosophical trend of his times and the influences which shaped it. Probably he had some knowledge of Buffon's (1749) writings in which the existence of a volcanic nucleus was advanced together with the universal ocean postulate of the great mathematician Leibnitz in 1680. Evidently he also had some premonitory notion of the views of the great Scottish geologist Hutton (1788) which in brief were to the effect that the ruins of the old world were visible in the present structure of the planet. The reasonings of Leibnitz were in view of our present knowledge quite sound in that he postulated that the planet originally was a burning luminous mass, which ever since its creation has been undergoing refrigeration.

There grew up at this period two schools of thought, the vulcanists versus the neptunists, whose discussions and disputes ran through a hundred years in attempts to reconcile their various views with the Mosaic doctrines at that time much more deeply imbedded in general beliefs than at present. Franklin's mind seemed to sense glimmerings of the evident unsoundness of the then almost universally accepted account of the beginnings of things. He had observed fossils, which he called sea-shells, at great elevations above sea level. Writing to Jared Eliot of Philadelphia, July 16, 1747, he states: "I mention mountains, that of the great Appalachian . . . show near the highest parts of them, strata of sea shells; in some places the marks of them are in solid rocks. It is certainly the *wreck* of the world we live on." Writing to Dubourg about the year 1770 he remarks: "I am persuaded, as well as you, that sea-coal has a vegetable origin, and that it has been formed near the surface of the earth; but as preceding convulsions of nature had served to bring it very deep in many places, and covered it with many different strata we are indebted to subsequent convulsions for having brought within our view the extremities of its veins so as to lead us to penetrate the earth in search of it."

[2] "The Origin of Continents and Oceans," Alfred Wegener, p. 2. E. P. Dutton and Company, New York, 1924.

Referring again to the Huttonion theory it may be said it was based on the exclusion of all causes not supposed to belong to the present order of nature. This is to a considerable degree sound reasoning much in accord with modern geological views. I can however find nothing in Franklin's writings in accord with it. Franklin was not a geologist and had no training in this branch of that science rather lightly regarded in his day and for many years after. He was however more or less familiar with the observations of European philosophers before and during his long life; the remarkable fact is he was so often nearly right in many of his conjectures, although at times, as might be expected, his speculations were rather wild according to modern knowledge and speculative deductions.

Albert Henry Smyth, the author of, "The Writings of Benjamin Franklin," Vol. I, p. 54, in referring to Franklin's essay published in the *Pennsylvania Gazette* on some "causes of earthquakes" says: "He adopted the thin crust theory of the earth, and recited the history of several famous instances of seismic disturbances." Smyth goes on to observe his (Franklin's) notions are so crude, and now so worthless and the whole essay so immature, "that I have seen no good reason to make room for it in this (1905) edition." As a matter of fact Franklin was in the main entirely right in his speculations, but then Smyth was not a geologist.

It seems difficult for the lay mind to appreciate that the crust of the earth is not rigid; it has never been. In fact it is in constant movement horizontal, vertical and torsional, else we would never have had any mountain chains and abysmal oceanic depths. Earthquakes are the consequence of this lack of stability and may occur anywhere at any time, varying of course in violence. No part of the world can be considered wholly free from the liability of such disturbances. They are certainly most frequent in distinctly volcanic areas or the vicinity of such sections. As a matter of fact there is probably no part of the world where in past geologic ages there has never been some form of volcanic or eruptive activity. Franklin evidently sensed something of the kind when he speaks of the ruin, wreck or bouleversement (overturn) of the earth's crust. He was probably personally un-

familiar with volcanic phenomena, never having had any opportunity of observing such activity.

Earthquakes are especially common in countries like Japan which are situated upon or near that great belt or line of volcanic disturbances extending from the southern extremity of South America north along the west coast of that continent, Central America, Mexico, California, Alaska, through the Aleutian Islands into Japan, thence into the East Indies. This is the world's major belt or line of disturbance. There are of course others of lesser magnitude. It is not, however, to be assumed that this belt is a continuous line of active volcanoes for such centers or spots are sometimes few and far apart in this long outline of weakness, but everywhere there are in it evidences of past volcanic and eruptive activity; indeed there are probably few or no spots on the earth's crust where some indications of such action could not be found if we go deep enough below the surface.

In physics and chemistry Franklin was in correspondence and probably personal contact with Priestley, Cavendish and Lavoisier. He was familiar with the new ideas concerning the properties of matter. In a postscript to a letter to Abbé Soulavie of September, 1782, he observes: "Men cannot make new matter of any kind; in the same manner may we not suppose that when we consume combustibles of all kinds, and produce heat or light, we do not create that light or heat; but only decompose a substance which received it originally as part of its composition?" This was certainly advanced thinking for that time and shows the influences of the chemists just mentioned.

In this same letter when speculating upon the magnetic properties of the earth Franklin mentions the existence of iron or ferruginous minerals in the interior of the earth to fit with his theory that the earth was a great magnet and that the "fluid of magnetism perhaps exists in all space." He further speculates on the shifting of the earth's axis and the variability of the poles.

Although Franklin admits "I have permitted myself to wander a little in the wilds of fancy" it is a notable fact that his speculations were shrewd, clever, and in not a few instances have been substantiated by modern research. It seems un-

likely he ever had been in correspondence with contemporary geologists, much less in personal contact with them; he does however appear to have been fairly well informed regarding many of their observations. It is evident his mind was greatly concerned with the magnetic properties, for we find this subject running frequently through his correspondence, one letter in particular to James Bowdoin dated Philadelphia, 31st of May, 1788, and read at a meeting of the Philosophical Society, January 15, 1790, he remarks: "Does not the apparent wreck of the surface of the globe, thrown up in long ridges of mountains, with strata in various positions, make probable that the internal mass is a fluid; but a fluid so dense as to float the heaviest substances? Is not the finding of great quantities of shells and bones of animals (natural to hot climates) in the cold ones of our present world, some proof that the poles have been changed?"

The influence of contemporary scientific thought and philosophy upon Franklin is evident. The eighteenth century marks the beginnings of modern scientific and mechanical development, a reaching out, a striving for the unknown never before equalled. The narrow confining trammels of the then generally accepted Pentateuchal doctrines were being questioned and rejected as no longer tenable. Alchemy had already grown into chemistry, the hypothetical theory of phlogiston was completely overthrown with the discovery of oxygen by Priestley in 1774, although he clung to this concept until his death in 1804, despite the more enlightened teachings of Lavoisier (1743–1794), who was the first to clearly realize that the air contained oxygen and that phlogiston was a mere figment of the imagination.

Franklin was undoubtedly influenced by Voltaire (1730–1760), whom he knew personally as well as by the writings of Rousseau (1712–1778). The "Principia" of Newton (1642–1727), whose fame for two hundred years, reigned supreme on all theories and speculations of cosmogony, had a profound influence upon the philosophical thinking of Franklin's time (he was twenty-one years old when Newton died), hence it is not difficult to understand the trend of Franklin's mind under the then advanced speculations of his time.

Probably the most remarkable characteristic of his great

intellect, a mind untrained by previous education and largely self-developed, was his quick apprehension and observation of all natural and scientific phenomena. His mind when not wholly absorbed or occupied with the common, ordinary affairs of life, strove to understand the whys and wherefores of the cosmos and it seems not unlikely had his life been wholly devoted to scientific observation, study and experiment he would have ranked as one of the greatest scientists and philosophers of history. But he lived in an age of rapid political change; the beginnings of a great nation absorbed his powers. He was very active in laying the sound foundations of our government which has withstood for one hundred and fifty years the shocks, stress, and the growing pains of a great nation.

GRAPHICAL ANALYSIS OF TRANSIENT PHENOMENA IN LINEAR FLOW.

BY

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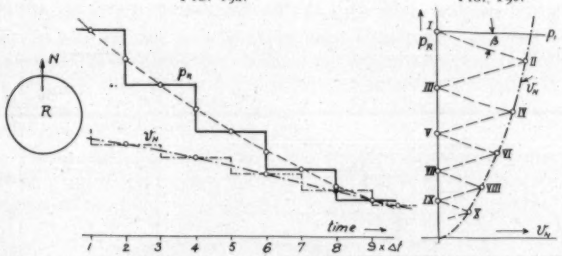
Associate Professor of Engineering Research, The Pennsylvania State College.

(*Continued from April issue*)

4. Storer and Nozzle (Figs. 19*a*, *b*).

It is assumed that a storer of R volume is charged to p_1 initial pressure. To it is connected an "open" nozzle of F area which is originally closed and then suddenly opened to its full area.

FIG. 19*a*. FIG. 19*b*.



Storer and nozzle: (*a*) history diagram; (*b*) v–p diagram.

In the v–p diagram the original condition is represented by point I, and the nozzle characteristic by the efflux parabola v_N as shown. During an arbitrarily assumed small time-interval Δt the pressure change will be (from Eq. 12):

$$p_2 - p_1 = k\frac{v_N F \Delta t}{R} = v_N \tan \beta.$$

By the end of the first interval the pressure has dropped to that of point II which is the intersection of the efflux parabola with the directrix $\tan \beta$ drawn from the I point; then the pressure drop continues to point III at the end of the second interval. During these two intervals the velocity of efflux varies according to the continually diminishing pressure values; but, as we are dealing with small time-intervals, a mean velocity of efflux, corresponding to point II can be

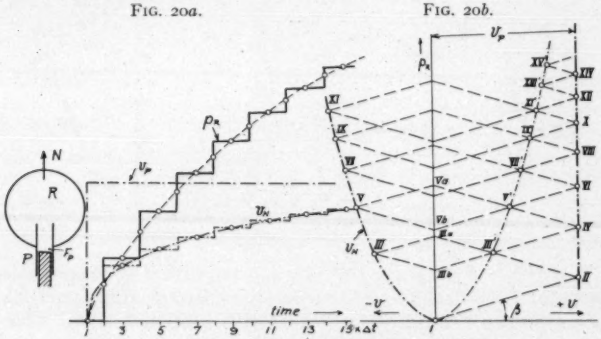
assumed to hold good during these two intervals. Continuing this construction the points *IV*, *V*, *VI*, ⋯ and so on can be obtained each point representing the pressures at the end of each consecutive interval.

Plotting in the history diagram the values of pressure and velocity v the stepped lines with diminishing ordinates are obtained. These will converge, as the time-interval Δt is made to approach zero, towards the continuously changing curves asymptotically approaching the abscissa axis as shown in the diagram.

5. Pump, Storer and Nozzle (Figs. 20*a*, *b*).

In the v–p diagram the pump-characteristic (v_P = const. on the positive side) and the nozzle-characteristic (z_N efflux-

FIG. 20*a*. FIG. 20*b*.



Pump, storer and nozzle: (*a*) history diagram; (*b*) v–p diagram.

parabola on the negative side) can be drawn. Both the v_P and the v_N have to be referred to the same cross-sectional area, preferably F_P, in which case the efflux parabola will be

$$v_N = \frac{F\,\text{nozzle}}{F\,\text{pump}} \sqrt{2g\frac{p}{\gamma}}. \tag{17}$$

The direction-tangent will be then the same for both the pump and for the nozzle, i.e.:

$$\tan\beta = \frac{kF_P\Delta t}{R}.$$

Starting from point I after the first Δt interval of influx the pressure II, and after the second interval the pressure III_a will be reached—assuming for the moment no efflux from the nozzle. The efflux from the nozzle can be assumed to take place consecutively, instead of—as it is actually the case—simultaneously. From point III_a efflux takes place which diminishes the pressure at the end of the first efflux-interval to III; at the end of the second interval the pump-influx increases the pressure to IV and Va, which will be again diminished by the subsequent efflux to V and Vb. This method can be continued, and the points VI, $VII \cdots XII$ obtained, the pressure and velocity values of which can be transferred into the history diagram.

Similarly to the case of two pumps with a storer (Figs. 18a, b) also in this case another simplified procedure can be followed. The efflux parabola is drawn on the positive side of the v–p diagram and its points of intersection with the directrices III', V', VII', IX', XI', $XIII'$ and so on obtained with greater clarity and less labor.

As the Δt approaches zero the stepped lines representing p and v approach more and more the continuous curves shown dotted in the history diagram.

6. Pump, Pipe and Storer (Figs. 21a, b, 22a, b).

If the hydraulic system comprises a pipe then the combined volume of storer and pipe will be $R + LF$.

In such cases it is practicable to choose the arbitrary time-element Δt to be equal to the "interval" of the pipe, i.e.: $\Delta t = L/a$.

With these values the equation of the storer (Eq. 12) can be written:

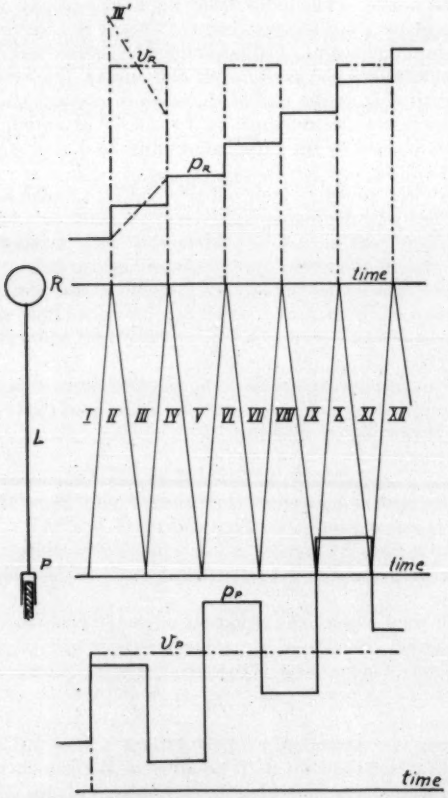
$$\frac{\Delta p}{v_1 - v_2} = \frac{k}{a}\frac{FL}{R + FL} = B = \tan\beta. \qquad (18)$$

If there is no storer ($R = 0$) then $\tan\beta = B = k/a = \tan\alpha$ which expresses the change of pressure in the presence of the pipe only, as it was found by the previous analysis.

If the storer is infinitely large ($R = \infty$) then: $\tan\beta = B = 0$, i.e., the pressure remains unchanged by an influx or efflux.

In general, $0 < \beta < \alpha$ for storers with finite volume. A number of examples will be given to illustrate the method.

FIG. 21a.

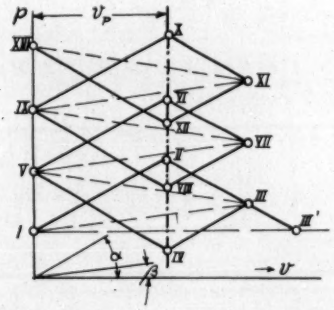


(*a*) *Charging a Storer of Finite Volume* (Figs. 21*a*, *b*). In this case

$$0 < \tan \beta = \frac{k}{a}\left(\frac{FL}{R + FL}\right) < \tan \alpha.$$

The initial state of flow is defined in the v–p diagram (Fig. 21*b*) by point *I* and the constant velocity of influx by v_P. After the beginning of pump-delivery in the first interval the condition at the pump-end is defined by point *II*. When this wave reaches the storer-end of the pipe the state of the first arriving liquid particles will assume the value *III'* (corresponding to the initial pressure). As more and more liquid arrives the pressure in the storer increases and the efflux-velocity from the pipe decreases, until, after an elapsed L/a interval it assumes the value *III*. This point is defined by the intersection of the *II*–*III'* line (denoting the change of

FIG. 21*b*.



Pump, pipe and storer of finite volume: (*a*) history diagram; (*b*) v–p diagram.

state in the pipe at the storer-end) and of the line *I*–*III* (denoting the change of pressure in the storer during one interval of traverse as the function of the velocity of influx into the storer). From this instant onward the pressure further increases and the velocity decreases, the condition at each instant being defined by a point in the *III*–*II* line. Thus at the storer-end both the velocity and pressure will change, but in order to simplify our reasoning we shall consider the mean values of v_3 and p_3 as being constant during this double interval, as denoted by point *III*.

On reaching the pump-end the velocity of this wave is reduced to the delivery-velocity at the cost of the pressure as defined by point *IV*. On reaching the storer-end the pressure

FIG. 22a.

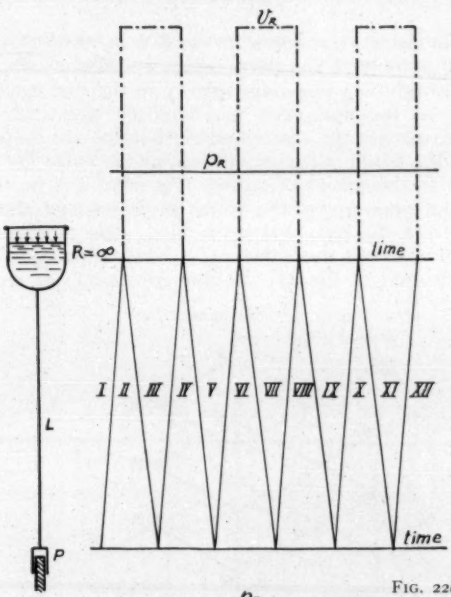
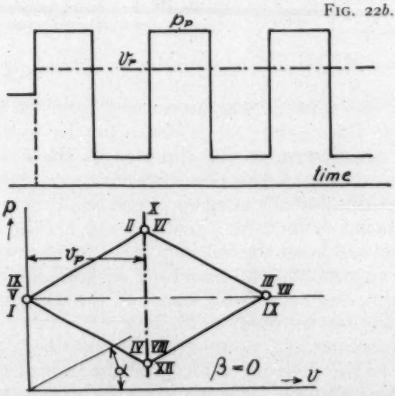


FIG. 22b.



Pump, pipe and storer of infinite volume: (*a*) history diagram; (*b*) v–p diagram.

is brought up to the value existing in the storer (point V) and the velocity is reduced to zero. From this point V the cycle starts anew and proceeds through points VI, VII, $VIII$, IX and the following cycle X, XI, XII, $XIII$ and so on until the delivery from the pump ceases.

(b) A particular case is when the storer-volume is zero, which is equivalent to charging a pipe:

$$R = 0; \qquad \tan \beta = \frac{k}{a}\left(\frac{FL}{R + FL}\right) = \frac{k}{a} = \tan \alpha.$$

This results in a diagram already dealt with (Figs. 7a, b).

(c) Another particular case is when the storer has infinite volume, which is characterized by the pressure p_R being unchanged by the influx of the liquid. In this case

$$\tan \beta = B = \frac{k}{a}\frac{FL}{R + FL} = 0.$$

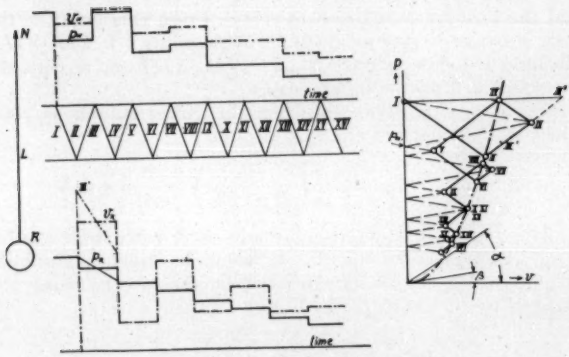
The construction is shown in Figs. 22a, b which do not require further elucidation.

7. Efflux from Charged Finite Storer through Pipe and Nozzle of Constant Area (Figs. 23a, b, 24a, b, 25a–e).

(a) In this case $0 < R < \infty$ and $0 < \beta < \alpha$.

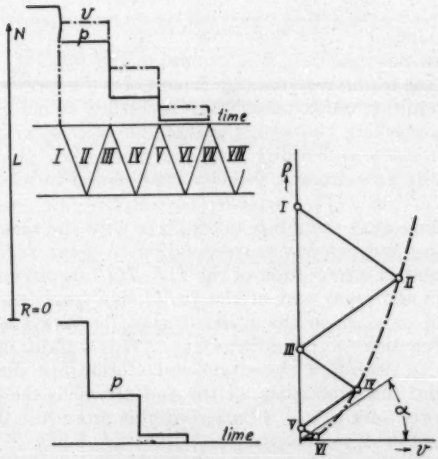
Starting in the v–p diagram from point I representing the initial condition efflux takes place according to state II; this wave on reaching the storer is restored momentarily to the initial pressure and influx into the pipe takes place under diminishing pressure and velocity represented by the portion of line III'' to III'. In order to simplify our analysis we shall assume that the influx takes place with the mean values of pressure and velocity corresponding to point III, defined as the point of intersection of the III'–III'' (representing the change in the pipe) and of the I–III line (representing the change of pressure in the storer during L/a interval of time as the function of efflux-velocity). This condition III is assumed to persist at the storer-end of the pipe during the second and third intervals, at the end of which the pressure in the storer sank to p_a. Continuing this procedure the efflux takes place in steps according to points VI, $VIII$, X $\cdots$ and so on until, after an infinite number of steps the discharge is completed.

FIG. 23a. FIG. 23b.



Storer of finite volume, pipe and open nozzle: (*a*) history diagram; (*b*) $v-p$ diagram.

FIG. 24a. FIG. 24b.



Pipe and open nozzle: (*a*) history diagram; (*b*) $v-p$ diagram.

(*b*) In Figs. 24*a*, *b* the particular case is illustrated in which the storer volume is zero, $R = 0$. This case is identical with the discharge from a pipe only.

FIG. 25*a*. FIG. 25*b*. FIG. 25*c*.

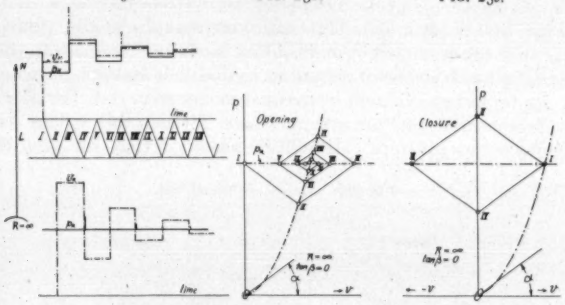
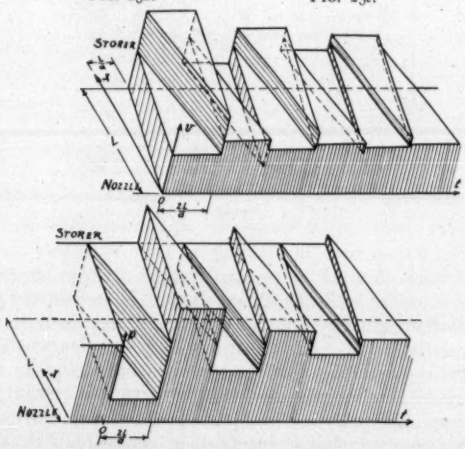


FIG. 25*d*. FIG. 25*e*.



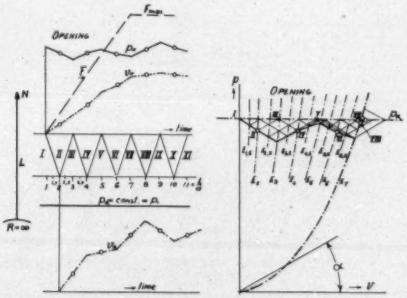
Storer pipe and open nozzle of infinite volume: (*a*) history diagram of opening; (*b*) p–t diagram of opening; (*c*) velocity stereogram of opening; (*d*) pressure stereogram of opening; (*e*) v–p diagram of closure.

(*c*) If the storer has infinite volume: $R = \infty$; $B = \tan \beta = 0$; $\beta = 0$; the efflux through an instantaneously opened

nozzle is defined by the construction shown in Figs. 25*a*, *b* which is also illustrated by the stereograms (Figs. 25*c*, *d*). The phenomena at sudden closure are illustrated in Fig. 25*e* (only the v–p diagram is shown).

(*d*) *Storer of Infinite Volume, Pipe, Nozzle of Variable Area* (Figs. 26*a*, *b*, 27*a*, *b*). This case corresponds to the timed-valve or common-rail system of fuel injection, and also to the opening and closing of a gate in hydraulic conduits. Owing to its importance it will be treated accurately, considering in each zone not constant mean values but variable values for velocity and pressure. It will be assumed that the area of

FIG. 26*a*. FIG. 26*b*.



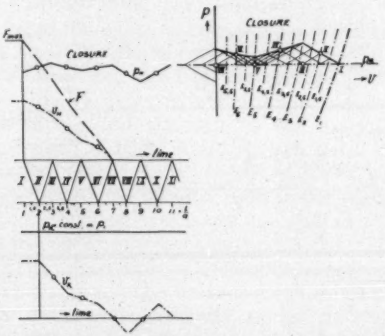
Storer of infinite volume, pipe and nozzle of variable area; opening: (*a*) history diagram; (*b*) v–p diagram.

the timed valve, both in opening-up from zero to $F_{max.}$ area, and in closure from $F_{max.}$ to zero area, is a linear function of time as it is shown in Figs. 26*a*, 27*a*. Therefore the nozzle characteristic is represented in the v–p diagram not by one efflux-parabola but by a multitude of parabolas, each being valid for a particular instant of time corresponding to the value of effective nozzle area at that particular instant.

A simplified analysis could be carried out with the assumption that in each double interval, in zones *II*, *IV*, *VI* ⋯ and so on, the nozzle area is constant corresponding to the mean value in that particular double interval. In this manner mean velocity and mean pressure values, constant for

each zone, should be determined, as shown by the encircled data points *II*, *III*, *IV*, *V* ··· and so on in the v–p diagrams and also in the history diagrams. It causes, however, no difficulty, only some extra labor and attention, to approximate to any desired extent the actual, variable conditions, by subdividing the time into fractions of one interval and carrying through the analysis with efflux parabolas valid for each fractional interval. In our example the time is subdivided into half intervals denoted in the time-abscissa by points 1, 1.5, 2, 2.5, to each of which corresponds an efflux-parabola E_1, $E_{1.5}$, E_2, $E_{2.5}$ ··· and so on.

FIG. 27*a*. FIG. 27*b*.



Storer of infinite volume, pipe and nozzle of variable area; closure: (*a*) history diagram; (*b*) v–p diagram.

Therefore, in the v–p diagram the velocity and pressure values at the nozzle in the zone *II* will lie on the intersection of the directrix (drawn at angle α from the *I* point) with the several efflux parabolas E_1, $E_{1.5}$, E_2, $E_{2.5}$ and E_3, these values can be plotted over the respective time-abscissas in the history diagram. In a similar manner, when the reflected wave reaches the storer-end of the pipe, and thereby its pressure changes to the original p_R value, the velocity values will be found at the intersection of the p_R = const. line with the directrices drawn from the formerly determined intersection points of the $E_{1.5}$, E_2, $E_{2.5}$, E_3 efflux-parabolas.

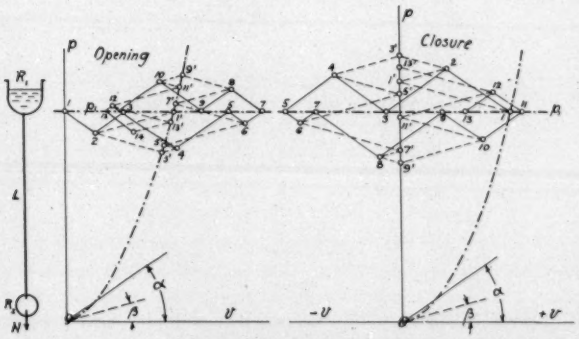
8. Storer, Pipe, Storer and Nozzle (Figs. 28*a*, *b*).

We have treated already the case of efflux from an infinite storer through a pipe and nozzle. We shall now investigate the effect of interposing a small storer R_2 in front of the nozzle. This case is analogous to that of a hydraulic system, R_1 representing the forebay or reservoir, L the conduit or penstock, R_2 the surge tank or air chamber and N the gate. The purpose of the surge-tank or air chamber is to reduce the pressure-rise in the pipe during the opening or closure of the gate.

In our analysis we shall assume

(1) that the nozzle is fully closed and then instantaneously fully opened;
(2) that the nozzle is fully open and then instantaneously fully closed.

FIG. 28*a*. FIG. 28*b*.



Storer, pipe, storer and nozzle: (*a*) v–p diagram of opening; (*b*) v–p diagram of closure.

The variations of pressure and velocity are shown in the v–p diagram, in Fig. 28*a* for the sudden opening, and in Fig. 28*b* for sudden closure. The amplitude of pressure and velocity surges are reduced in comparison with systems without surge tank. Increasing the R_2 would entail a decrease of $\tan \beta$ and therefore lessening the amplitude of the pressure fluctuations.

(To be continued)

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

ATMOSPHERIC CORROSION TESTING.

Metallurgists have long been "corrosion-conscious" and this state of mind is rapidly extending to metal users in general. Methods for determining the corrodibility of metals vary greatly, and uniformity in testing of this kind is greatly to be desired. With this thought in mind, the American Society for Testing Materials, through its corrosion committees, arranged for a discussion of the subject at its annual meeting last month. As a contribution toward this symposium, H. S. Rawdon, chief of the Bureau's Metallurgical Division, presented a paper on atmospheric corrosion testing. Such testing is of vital concern to the manufacturers of paints, lacquers and coating materials in general as well as to the metal users, particularly those of sheet metal. The marked trend toward the architectural use of metals for both decorative and structural purposes, as well as the increased use of metal in trains, automobiles, and aircraft, have served to emphasize the importance of atmospheric corrosion testing. In Mr. Rawdon's paper, the various methods of carrying out tests of this kind were critically reviewed. Some of the outstanding points in this résumé are as follows:

Laboratory tests are usually carried out for a specific purpose. Their indications with respect to the serviceability of any material should be confirmed by field tests, which latter, however, are not always to be regarded as identical with service.

The results of atmospheric field exposure tests should always be correlated with the prevailing atmospheric conditions at the test location. It is not uncommon that conclusions based on results obtained at one location are wholly inapplicable under other conditions. The prevailing atmospheric conditions obtaining at any test site, particularly the

* Communicated by the Director.

degree of pollution of the air, should be known with considerable certainty. Some cognizance should also be taken of the season at which outdoor field tests are started.

A relatively large surface area with respect to the mass of the specimen is always advantageous for atmospheric corrosion tests. When the progress of corrosion is to be followed by change-of-weight determinations a large area : weight ratio is required. This practically limits such tests to sheet or similar material.

For field exposure tests, the specimens should be supported on rigid permanent supports in such a manner that no specimen is influenced through contact, rain drip, or otherwise by another specimen or by the supports used. The necessary supporting points should be restricted to contact with inert nonmetallic materials. Exposure toward the south at an angle of 30 to 45 degrees with the horizontal is a favored method for sheets. A distinction should be made between the results obtained on the lower surfaces and those on the upper surfaces in such cases.

Most tests of this kind are carried out by determining the change of weight of the specimen occurring during exposure to the weather. The usual precautions for cleaning the materials before and after they are exposed to the weather must, of course, be observed.

In some cases it is most helpful to determine the change in the mechanical properties of the materials resulting from corrosion. This is especially applicable to some of the thin-gage sheet materials used in aircraft construction. Information on the possible loss of strength or ductility of a metal is much more useful in an engineering sense than information on the loss of weight.

CONFERENCE ON UNDERGROUND CORROSION.

As the result of many discussions with those interested in the corrosion of underground piping systems, the Bureau has decided to sponsor a conference on this subject, probably during October, 1937. The purpose of the conference will be the exchange of ideas among those engaged in the investigation or mitigation of underground corrosion.

In order to facilitate the exchange of ideas and to limit the attendance to those who have contributions to make, participation will be limited to representatives of organizations presenting heretofore unpublished papers or reports on some phase of underground corrosion. Each organization presenting a paper will be allowed as many representatives as it desires, provided each of them is engaged in the mitigation of corrosion as a part of his duties.

Each organization will be asked to supply for exchange as many copies of its paper as there are papers to be presented to the conference in order that each participant may receive a copy of each paper. This will require about 40 copies which should be forwarded to the National Bureau of Standards, attention of K. H. Logan, who will effect the exchange of the papers. The papers should be forwarded at least 30 days prior to the conference. The papers will remain the property of the authors who may publish them or not, subsequent to the meeting. The unexchanged copies of the papers will be returned to the authors.

The following topics for discussion have been suggested:

1. Theory of underground corrosion.
    - *a*. Mechanism of corrosion.
    - *b*. Chemical effect of soils.
    - *c*. Relation of soil types to corrosion.
    - *d*. The corrosion of lead.
2. Standardization.
    - *a*. Methods for determining the corrosivity of soils.
    - *b*. Methods for determining the condition of pipe lines.
    - *c*. Tests and specifications for pipe coatings.
3. Stray current electrolysis—Long-line currents.
4. Cathodic protection.
5. Miscellaneous papers related to corrosion.

Papers on several of these subjects have been offered and an effort will be made to secure papers on the other subjects from competent authors.

It is hoped that as many as possible of the authors of papers will attend the conference, since the discussion of the papers and the informal interchange of ideas is an important part of such a gathering. However, in former conferences there have

been a number of students of corrosion who wished to interchange ideas but who lived too far from Washington to justify attendance. As on former occasions, such men will be permitted to send papers for exchange and will receive in return copies of all papers submitted for discussion.

This arrangement permits an interchange of ideas between persons in all parts of the United States and abroad. It is hoped that several papers from European authorities on underground corrosion will be received.

The date for the conference will be set to meet the convenience of the majority of the participants, but as already stated, it will be held in October 1937. It is desired that all interested shall have ample time for the preparation of worthwhile papers or reports.

If any reader of this Bulletin desires to participate in the conference, please notify K. H. Logan stating the subject or general nature of your contribution at your earliest convenience, together with your preference as to the date of the conference.

CONSTITUENTS OF PORTLAND CEMENT CLINKER.

Phase equilibrium studies on many of the systems involving the oxides which occur in significant amounts in portland cement clinker have shown what compounds are formed under equilibrium conditions. Of late, various investigators have found evidence by X-ray and optical methods that some of the principal constituents of clinker contain detectable and important amounts of other constituents in solid solutions. Recent work at the Bureau by H. F. McMurdie has been concerned with the area $CaC - 4CaO.Al_2O_3.Fe_2O_3 - CaO.Al_2O_3$, and special attention has been paid to the occurrence of solid solution. As reported in the April number of the *Journal of Research* (RP987), it was found that all three calcium aluminates ($3CaO.Al_2O_3$, $CaO.Al_2O_3$ and $5CaO.3Al_2O_3$) dissolve Fe_2O_3 in amounts up to 2.5 per cent. The $4CaO.Al_2O_3.Fe_2O_3$ also dissolves the aluminates in amounts between 3 and 5 per cent. In some cases the solid solution relations are such as to shift the conjugation lines away from the joins.

PROPERTIES OF STEAM.

A calorimetric determination has been made by Drs. N. S. Osborne, H. F. Stimson, and D. C. Ginnings, of the thermal properties of saturated water, in both the liquid and gaseous states, from 100° C. (56 kg./cm.^{2}) to the close vicinity of the critical point, 374° C. (225 kg./cm.^{2}). This new determination supplements a previous determination in the same laboratory in the range from 0 to 270° C. With the new apparatus designed and built to withstand severe conditions of temperature and pressure, satisfactory measurements were possible up to within one degree of the critical point.

Special tests of the possibility of mixture of the liquid and vapor phases in evaporation experiments indicated freedom from this effect, except within one degree of the critical point. These tests included direct measurements of specific volume at 370° C., which confirmed the calorimetric results.

A compilation was made of the thermal properties of saturated water in the interval from 100 to 374° C., giving the vapor pressure and the specific volume, entropy, and enthalpy or heat content for both the liquid and gaseous states. This compilation is based on the results of the present measurements, supplemented by data covering the range from 100 to 270° C. from the previous investigation. These latter data are in accord with those of the present investigation at the same temperatures. In RP983 (*Journal of Research* for April) in which this work is reported, a number of comparisons between these values and certain groups of similar data from other laboratories are shown graphically.

SPEED CONTROL FOR SCREW-POWER TESTING MACHINES DRIVEN BY DIRECT CURRENT MOTORS.

The speeds at which mechanical tests are to be made are specified more definitely in modern rules of testing procedure than in those formerly followed. Speed control for testing machines hydraulically driven is obtained by the manipulation of either the main or the relief valve, or both, and is comparatively simple. The range of platen speeds for the older types of testing machines which have constant ratios of

platen to motor speed is generally restricted. Many of these machines are, however, in service. Believing that a description of the method of speed control for this type of machine (which has been in use at the Bureau for several years) might be of value, an article on the subject has been prepared by Ambrose H. Stang and Leroy R. Sweetman for publication in the Proceedings of the American Society for Testing Materials. The method has long been known, but not as widely as its usefulness warrants, and so far as the writers are aware, it has not been applied elsewhere to testing machines. The method consists of retaining the rated voltage on the field of the direct current shunt motor and also on a rheostat. The armature voltage is varied through the utilization of the potentiometer principle, by making electric contact between the armature leads and various portions of the rheostat, with resultant change in motor speed. The method has been used to obtain definite speeds of platen travel not given by the gear shifts, to obtain very slow speeds for use in calibration and stress-strain determinations, and to obtain definite rates of stress increase in the specimen. It has been used for motors having a power rating as great as 15 horsepower.

PRECISION CAMERA FOR TESTING LENSES.

Before an airplane camera lens is used on a mapping project, exact information on its freedom from distortion and the quality of definition should be available. This has been so generally recognized that the United States Army does not permit the installation of lenses in its cameras without preliminary tests, and the civilian government mapping agencies require, in their contracts, that all bids for mapping projects shall be accompanied by reports from the National Bureau of Standards concerning the lenses to be used. The American Photogrammetric Society has recently issued standard specifications for airplane photography and these contain detailed requirements for lens performance.

Formerly airplane mapping in this country was largely non-stereoscopic, elevations not being measured. Recently, however, the emphasis has been shifted to stereoscopic methods, and this will necessarily result in much more strin-

gent requirements for the lens and camera. In accordance with this increased importance of airplane mapping, Dr. Irvine C. Gardner and Frank A. Case of the Bureau's optical instruments section have developed and constructed an apparatus for testing airplane lenses and cameras. No outdoor targets are used, a group of collimators providing test charts which, optically, are infinitely distant. Test exposures are made, and from an examination of the resulting negative complete information can be obtained concerning the back focal length, equivalent focal length, and both the distortion and the quality of definition in all parts of the field. The test can be made upon the lens in its barrel, or may be applied to the lens and camera as assembled. In this last case one obtains the constants of the lens corresponding to the particular image plane determined by the construction of the camera. The negative made during the test is a convenient record of the performance of the lens.

The complete description of this precision lens-testing camera will be published as RP984 in the April number of the *Journal of Research*.

TRAFFIC OR ZONE PAINTS.

Owing to the ever increasing number of automobiles, the subject of traffic or zone paint is becoming more important. The painting of surfaces of highways to designate lanes of travel, and the marking of crosswalk boundaries, parking spaces, special directional lines, curbs, obstructions, etc., are coming into more general use. These markings are of great assistance to a driver, and tend to promote the safety of both driver and pedestrian. For special purposes, particularly in heavily congested traffic areas, round and rectangular inserts of aluminum, non-rusting steel, monel metal, brass, etc., are used with good results. However, paint is more extensively used because it can be cheaply applied and readily renewed. Many thousands of dollars are spent annually by States and municipalities in buying and applying traffic paint. These paints are of a different type from ordinary paints and vary greatly in durability. Since the cost of application is two or three times the cost of the paint, a method of testing which

will determine relative durability may result in large savings to the public.

In coöperation with the District of Columbia, the Bureau has been testing traffic paint for the past 10 years. Experience has been gained from actual road tests of a large variety of both commercial and experimental paints. This has led to the development of specifications, and a machine for measuring the relative wear of traffic paints. A distinct improvement in durability of the traffic paints in actual service has resulted. A publication on this subject will appear as a Circular of the Scientific Section, National Paint, Varnish and Lacquer Association, Inc., 2201 New York Avenue, N. W., Washington, D. C.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, APRIL 21, 1937.

The stated monthly meeting of the Institute was called to order by Mr. W. Chattin Wetherill, Vice-President, at 8:30 o'clock. The minutes of the previous meeting were approved as printed in the April issue of the JOURNAL.

The Secretary announced that the following additions had been made to the membership since last report: Institute—22, Museum—44, total 66.

He also announced that the closing lecture of the current season would be given on the evening of Thursday, the 29th, when Dr. Ernest O. Lawrence of the University of California will speak on "Nuclear Physics, Nuclear Chemistry, and Biology."

Attention was also called to a new series of demonstrations on electrochemistry which will be given daily (except Mondays and Tuesdays) in the lecture hall beginning on May 7th. Mention was also made of the Medal Day meeting of the Institute, to be held on May 19th, when the several medals recommended by the Committee on Science and the Arts during the past year will be presented to the several recipients. Dr. Robert Andrews Millikan of Pasadena, California, and Dr. Peter Joseph Wilhelm Debye of Berlin, Germany, will receive the Franklin Medal.

The chairman then introduced Dr. W. F. G. Swann, Director of the Bartol Research Foundation, who presented an account of the activities of the Foundation during the year 1936. The work of the several departments was reviewed and special attention was given to the investigations on nuclear physics and cosmic rays. The subject was illustrated by lantern slides, moving pictures and a number of startling experiments. After a brief discussion the chairman conveyed the thanks of the meeting to the speaker.

Adjourned.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 14, 1937.)

HALL OF THE COMMITTEE,
PHILADELPHIA, APRIL 14, 1937.

DR. WINTHROP R. WRIGHT *in the Chair.*

The following reports were presented for final action:

No. 3021: Magnetic Resonance Accelerator.

This report recommended the award of an Elliott Cresson Medal to Prof. Ernest O. Lawrence, of Berkeley, California, "In consideration of his development

of the cyclotron, an apparatus for accelerating ions which embodies a high degree of technical skill and is of material use in extending the knowledge of nuclear physics."

No. 3030: Developments in Chemical Microscopy.

This report recommended the award of an Edward Longstreth Medal to Dr. Emile Monnin Chamot, of Ithaca, New York, "In consideration of his meritorious work in the field of microchemical analysis."

JOHN FRAZER,
Secretary to the Committee.

LIBRARY NOTES.

The library is open for consultation as follows: Mondays, Tuesdays, Fridays and Saturdays, 9 A.M. until 5 P.M., Wednesdays and Thursdays, 2 until 10 o'clock P.M. 702 readers consulted the library during the twenty-six days of March.

RECENT ADDITIONS.

Architecture and Building.

American Society of Heating and Ventilating Engineers. Guide. Volume 15. 1937.

DALZELL, J. RALPH, AND JAMES MCKINNEY. Air Conditioning—Insulation. 1937.

Astronomy.

VAN DEN BERGH, G. The Universe in Space and Time. Translated by Joan C. H. Marshall and Th. de Vrijer. 1937.

Biochemistry.

HALLIBURTON, W. D., J. A. HEWITT, AND W. ROBSON. The Essentials of Chemical Physiology for the Use of Students. Thirteenth Edition. 1936.

NORD, F. F., AND R. WEIDENHAGEN. Ergebnisse der Enzymforschung ter Band mit Sachregister zu Band 1–6. 1937.

Royal Society of London. Philosophical Transactions. Series B. Volume 226. 1936.

SHERMAN, HENRY C. Chemistry of Food and Nutrition. Fifth Edition Completely Rewritten. 1937.

Biography.

HOOKE, ROBERT. The Diary of Robert Hooke, M.A., M.D., F.R.S. 1672–1680. Transcribed from the Original in the Possession of the Corporation of the City of London (Guildhall Library). Edited by Henry W. Robinson and Walter Adams. 1935.

STUKELEY, WILLIAM. Memoirs of Sir Isaac Newton's Life . . . 1752. Being Some Account of his Family and Chiefly of the Junior Part of his Life. Edited by A. Hastings White. 1936.

Chemistry.

ALEXANDER, JEROME. Colloid Chemistry: Principles and Applications. Fourth Edition. 1937.

American Institute of Chemical Engineers. Transactions 1936, Volume 32. 1937.

BRANDENBURGER, KURT. Pressmischungen, geschichtete Produkte und deren Aufbereitung. 1937. Herstellung und Verarbeitung von Kunstharzpressmassen. Band 4.

CLOUD, WILBUR F. Petroleum Production. 1937.

GARDNER, HENRY A. Physical and Chemical Examination of Paints, Varnishes, Lacquers and Colors. Eighth Edition. 1937.

Organic Syntheses. Volume 17. 1937.

PRENTISS, AUGUSTIN M. Chemicals in War. A Treatise on Chemical Warfare with Chapters on the Protection of Civil Populations and International Situation by George J. B. Fisher. First Edition. 1937.

Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Volume 21. 1936.

WHITMORE, FRANK C. Organic Chemistry. 1937.

Electricity and Electrical Engineering.

Lincoln Electric Company. Procedure Handbook of Arc Welding Design and Practice. Fourth Edition. 1936.

MOYER, JAMES A., AND JOHN F. WOSTREL. Industrial Electricity and Wiring. Second Edition. 1937.

PALM, A. Elektrische Messgeräte und Messeinrichtungen. 1937.

P E P (Political and Economic Planning). Report on the Supply of Electricity in Great Britain. A Survey of Present-Day Problems of the Industry with Proposals for Reorganization of Electricity Distribution. 1936.

REYNER, J. H. Radio Interference and Its Suppression. 1936.

Engineering.

SPOFFORD, CHARLES M. The Theory of Continuous Structures and Arches. First Edition. 1937.

Hygiene.

KOELSCH, FRANZ. Lehrbuch der Gewerbehygiene. 1937.

Mathematics.

CRENSHAW, BOLLING H., AND CINCINNATUS D. KILLEBREW. Analytic Geometry and Calculus. Second Edition, Revised by Ralph D. Doner. 1937.

GAVETT, G. IRVING. A First Course in Statistical Method. Second Edition. 1937.

HOGBEN, LANCELOT. Mathematics for the Million. 1937.

Mechanical Engineering.

METZELTIN, E. Die Lokomotive feiert mit das 100 jährige Bestehen der Deutschen Eisenbahnen. 1935.

PURDAY, H. F. P. Diesel Engine Design. Fourth Edition. 1937.

STAUBER, G. Gasmaschinen und Kompressoren mit Wasserkolben. 1937.

Metallurgy.

FRÖHLICH, HERBERT. Elektronentheorie der Metalle, 1936. Struktur und Eigenschaften der Materie XVIII.

ROSE, SIR THOMAS KIRKE, AND W. A. C. NEWMAN. The Metallurgy of Gold. Seventh Edition, Revised Throughout and Re-set. 1937.

WILSON, A. H. The Theory of Metals. Based on an Essay Awarded the Adams Prize in the University of Cambridge 1931–1932. 1936.

Pharmacy.

American Pharmaceutical Association. Year Books 1933 and 1934, Volumes 22 and 23. 1935–1936.

British Pharmacopœia Adendum to 1932. 1936.

Gehe & Co. A.-G. Gehes Codex. Siebente, neu gestaltete Auflage. 1937.

JENKINS, GLENN L., AND ANDREW G. DUMEZ. Quantitative Pharmaceutical Chemistry Containing Theory and Practice of Quantitative Analysis Applied to Pharmacy. Second Edition. 1937.

Photography.

CHAMPLIN, HARRY. Champlin on Fine Grain. 1937.

JORDAN, FRANKLIN I. Photographic Enlarging. 1935.

PILLSBURY, ARTHUR C. Picturing Miracles of Plant and Animal Life. 1937.

Scientific Essays and History.

GUNTHER, R. T. Early Science in Cambridge. 1937.

JASTROW, JOSEPH, Editor. The Story of Human Error. 1936.

Sugar.

DALTON, JOHN E. Sugar. A Case Study of Government Control. 1937.

BOOK REVIEWS.

EINFÜHRUNG IN DIE KLASSISCHE ELEKTRODYNAMIK, von Dr. Johannes Fischer. 199 pages, diagrams, 17.5 × 26 cms. Berlin, Julius Springer, 1936. Price 12 RM.

The author points out that this book is an introduction to classical electrodynamics rather than a text book and refers to the difficulty frequently experienced by beginners in getting accustomed to the concepts of the electric and magnetic field. By presenting a work from the standpoint of an introduction the author aims to eliminate this difficulty and to bring together the concept of the physicist and the engineer.

The book is divided into two parts. The first, covering the treatment on the electric and magnetic field as distinct from any mutual relation, is subdivided into chapters on the electrostatic field in vacuo; the electrostatic field in the case of nonconductors; electrostatic calculation methods; the magnetostatic field; and the electric field of flow in conductors. The second part of the book is devoted to mutually interlinked phenomena and discusses this through sub-topics on laws of interlinkage; quasi stationary processes; and propagation phenomena. Following these two main divisions there is a short treatment of the units and measuring systems used in the book.

There is a name and subject index in the back of the book. There are occasional footnotes throughout and there is a short historical paragraph leading up to the subject. The work may be recommended to students of the subject in that its approach is from an unusual angle.

R. H. OPPERMANN.

THE THEORY OF METALS, by A. H. Wilson. 272 pages, diagrams, 14.5 × 22.5 cms. Cambridge, University Press, 1936. Price $5.00.

In the Preface of this book the author states, "The electron theory of metals, after having made great advances during the past ten years, has now become so far consolidated that we may safely say that most of the underlying principles have been discovered, and that the near future will see refinements of the theory rather than entirely new developments. The present is therefore a suitable time for a critical survey of the whole field."

The plan of the book is such that its contents are based on the first two chapters. These are the introductory chapters, the first giving a historical introduction and the second being devoted to the general theory of the motion of electrons in a perfect lattice. The ideas here introduced are applied to various problems in the remaining chapters. Chapter III is concerned with equilibrium properties such as the number of free electrons in metals, alloys and semi-conductors, together with the more difficult questions such as cohesion and diamagnetism. Optical properties of metals are dealt with followed by the treatment on the formal theory of conduction. This is especially interesting. In the beginning of the book there is discussed Lorentz's theory of conduction wherein the resistance is due to the elastic collisions of the conduction electrons with metal atoms, and this is supplemented here by the formal theory. A theory is set up similar to Lorentz's, but which does not particularize the mechanism producing the resistance. Assumption is made that the electrons can be considered as moving practically independently of one another and the distribution function determined. In the chapter following this the mechanism of conductivity is discussed through sub-topics as the lattice vibrations, the coupling between the electronic and lattice motions, the existence of a free path at high temperatures, etc. The last chapter of the book is concerned with the problem of superconductivity.

There are two appendices—the Fermi-Dirac statistics, and surface phenomena such as thermionic emission and rectification by crystal contacts. A list of symbols and a subject and name index complete the book.

The work is an interesting presentation of a subject necessarily involving the use of mathematics to a considerable extent. It is a valuable work not only for its contribution of definite knowledge but for its ability to inspire thought.

R. H. OPPERMANN.

DIELECTRIC PHENOMENA IN HIGH VOLTAGE CABLES, by D. M. Robinson, Ph.D., with a foreword by P. V. Hunter, C.B.E. 173 pages, plates, diagrams, 14 × 22 cms. Pittsburgh, Instruments Publishing Company, 1936.

As the reader will at once note, the subject of this book is a highly specialized part of electrical technology. The need for such knowledge has increased in great strides in proportion to the increasing requirements of high voltage cable. Quite a

number of years ago it was recognized that research must go hand in hand with cable manufacture to make and operate cables at high voltages and at varying temperatures. A book combining all useful knowledge on the performance of the dielectric and the way in which that performance may be affected by the construction and subsequent history of the cable should certainly be a worth while and valuable addition to engineering literature.

The book deals with the only dielectric in general use in modern cables for voltages of 11,000 v. and above, namely, paper impregnated with mineral oil, with or without the addition of rosin. After an introduction there is given an outline of the methods by which it is possible to produce and study phenomena in cable dielectrics in laboratory tested cables, and the measures adopted when simulating working conditions. Following this, failures by the tracking mechanism and by thermal instability are discussed. Puncture breakdown due to d.c. stress, extremely high a.c. stress for a few seconds, and surges are next treated. Subsequent subjects include mixed breakdowns and the problem of tracking, the formation and significance of voids, dielectric loss, barrier action, surface stress, and finally, cable design. In this latter subject the various types of cable available are discussed in relation to the known mechanism of breakdown and factors influencing the choice of cable type are mentioned.

The book is well planned and the method of presentation very well done in as simple and understandable manner as possible. There are a great many illustrations and photos which assist very materially. A summary and bibliography appear at the end of each chapter. A subject index completes the book.

There should be considerable demand for this book because it is an outstanding treatment on phenomena connected with both operation and testing and of appropriate methods of prooving materials for use in the solid type cable.

R. H. OPPERMANN.

KERNPHYSIK VORTRÄGE GEHALTEN AM PHYSIKALISCHEN INSTITUT DER EIDGENOSSISCHEN TECHNISCHEN HOCHSCHULE ZURICH IM SOMMER 1936 (30. Juni–4. Juli), herausgegeben von Dr. E. Bretscher. 141 pages, diagrams, 16 × 24.5 cms. Berlin, Julius Springer, 1936. Price 12 marks.

Every two to three years the Physikalische Institut der Eidgenossischen Technischen Hochschule, Zürich, devotes a week to lectures by prominent authorities on physical topics. This book contains those lectures delivered during the week for 1936. The papers are divided into three parts—Kernphysik, Experiment und Photonentheorie des Compton-Effekts, and Kosmische Strahlung. Authors of the papers are from Germany, England, France, and the United States and their essays are recorded in the languages of these countries. There are seventeen papers in all which have been prepared for publication by Dr. E. Bretscher of Zürich who has also supplied the preface and the introductory article.

R. H. OPPERMANN.

SELECTED WRITINGS OF ABRAM S. HEWITT, edited by Allan Nevins, with an introduction by Nicholas Murray Butler. 414 pages, 16 × 24 cms. New York, Columbia University Press, 1937. Price $3.50.

Much is being said these days regarding the usefulness of the engineer in public life and his ability or lack of ability to meet problems of politics and

economics. There are a number of engineers who as prominent citizens have achieved greatness and fame in other fields of endeavor than engineering. One such man was Abram S. Hewitt 1822–1903. He had the reputation of being America's foremost ironmaster of the generation just before Carnegie and was in addition one of the most important figures in his day in politics and government. His engineering achievements include his activities with Edward Cooper and Charles Hewitt in the perfecting of the manufacture of wrought iron structural beams; giving the Bessemer process the first American trial at Phillipsburg, N. J.; assisting Cyrus W. Field and Peter Cooper in work of laying the Atlantic cable; manufacture of gun metal for Union armies during the Civil War. Abram Hewitt was the principal Democratic leader in the House of Representatives for fifteen years and was one of the best mayors of New York City.

The papers in this book reflect the intellectual and public activity of a foremost citizen and leader. They are divided in the listing of contents as autobiographical papers, iron and steel, political, capital and labor, the government of New York City, and papers on education. Of particular general interest should be Hewitt's account of his own relation to the settlement of the disputed presidential election of 1876. It has been stated that this document has never before been published in full and his position in the House of Representatives made it possible for him to be in very close contact with happenings of the time.

R. H. OPPERMANN.

ELECTRICITY AND MAGNETISM, by A. W. Hirst, M.Sc. 388 pages, illustrations, 15.5 × 23 cms. New York, Prentice-Hall, Inc., 1937. Price $4.50.

The author presents here a text written with the underlying thought that a thorough background of fundamentals is invaluable to the technical worker. The book, therefore, aims to give an appreciation of theoretical principles in an introductory way for courses in the science of electricity and magnetism. With this statement it may be imagined that the treatment is somewhat heavy and difficult to follow. This, however, is not the case, as it would be hard to find a more clearly written book. This is one of the main features—clarity, impressionable, and inspirational. The author's style, plus the different kinds of type used, and plus the many diagrams and illustrations rightly placed, make it so.

The work begins with an introductory chapter presenting a summary of the common systems of units and of mathematical principles later employed. Then the student is taken into the relation of electricity and matter, and the relation of electricity and energy, giving definitions of what electricity is. A chapter follows describing some of the effects produced by an electric current and their practical applications. The current is assumed to be flowing along a conductor, but no precise inquiry is made as to its origin. This is left to later sections.

With this as a basis the reader is then given successive discussions on magnetism, the electric circuit, resistance and thermo-electricity, electrolysis, electromagnetism, induction, measuring instruments, magnetization of iron and steel, the magnetic circuit, elementary alternating currents, principles of electric machines, and principles of electrostatics. It can be seen from this sequence that the progression is orderly and logical.

After the groundwork in this book has been completed, there are lists of well chosen and well formed problems at the end of the chapters, in order to give

exercises. The solutions are given in the back of the book. In addition to being of unusually good construction as a text, it should prove equally valuable as a reference work. The subject index helps considerably in locating material.

Students who propose to work along lines covered by the subject of this book would do well to examine it both for purposes of using it as a text and as a reference later.

R. H. OPPERMANN.

THE IDENTITY THEORY, by Blamey Stevens, 2d edition. 259 pages, 14.5 × 22 cms. Manchester, Sherratt & Hughes, 1936. Price 7s. 6d.

This is the second edition of this work, the first having appeared in 1929. It is a somewhat involved analytic treatment on identics. At the very beginning of the book in explaining what is meant by identity the author, referring to what the physicist calls laws of nature, states, "The individual has several senses, and a variety of ways of interpreting the messages that they bring to his mental equipment. In virtue of these differences he senses the same thing in different ways. When he finds by experiment that two of these ways can be equated, he calls the equation a law of nature. In reality they are the same things measured in different ways, so that we prefer to call the equation an identity."

There are two postulates stated to this theory, the first postulate being the identity of inertia, space and time. These three terms are each complete, symmetrical primals, for measuring the same thing, which is called substance. The second postulate introduces the variant property of space.

There are twenty-two chapters to this book of some 248 pages. The text is divided into articles, each of which presents a single deductive or inductive argument. Each chapter is provided with an introduction which serves to orient the reader. After giving analogies and a psychological aspect of the subject, the treatment enters the discusson of the exact expression of the theory, then gives preliminary definitions of measurement, and proceeds through chapters on space-time identity, the inertia-space identity, space-time mechanics, identical entities, momentum propagation, identic relativity, etc. The author states that the first sixteen chapters of the book seem to constitute a thorough proof of the theory. The remaining chapters might be considered to be an attempt to solve the jig-saw puzzle of the physical universe. These include topics of the gravity sphere, radiation, identic aspect of quantum problem, etc.

There is a table of contents in the front of the book, and a glossary and two tables of constants in the back. For those who have the required mental equipment the book should prove interesting.

R. H. OPPERMANN.

THE HANDMAIDEN OF THE SCIENCES, by Eric Temple Bell. 216 pages, illustrations, 14.5 × 22 cms. Baltimore, The Williams and Wilkins Company, 1937. Price $2.00.

In this book, there is laid before the reader a narrative on the use of mathematics in science, from the work and conceptions of the early mathematicians and scientists to the present. Obviously, one would think, a book of this nature would not only be very large but very uninteresting due to its extreme theoretical treatment. An examination of this work however reveals an interesting narrative

of some 215 pages within the intellectual capabilities of most people not directly associated with mathematics or with science.

The author begins with discussing generally mathematics and science, examining the claims and the challenges that mathematics is a powerful aid in scientific research and the distinction between the mathematical method and the scientific method. Then, in a chapter entitled "From Cyzicus to Neptune," the author traces mathematics and science from Menaechmus (375–325 B.C.) to the discovery of Neptune by pure mathematical analysis applied to a great physical hypothesis. Attempts to describe the physical universe is next discussed, and the concepts of continuity as in motion and discreteness as in atomism are illustrated.

With these subjects the book begins. They may serve as an illustration of how the rest of the general subject matter is dealt with. Succeeding chapters are covered in somewhat like manner. There are discussed the expedients resorted to by scientists, mathematics being one and in many instances one of the less important; the content of mathematics which is used and unused; thinking by means of graphic representation; the use of numbers as measuring distances; verified predictions of the theory of general relativity; probability; the prediction of wireless waves by James Clark Maxwell.

The author has a knack of writing that is captivating. While some few parts of the book may be questioned at first glance, the work as a whole is well presented. It is thought provoking, interesting, informative, and a contribution to the literature that should be much sought for.

R. H. OPPERMANN.

CUGLE'S EXAMINATION GUIDE FOR LIFEBOAT MEN AND SEAMEN, by Charles H. Cugle. 188 pages, illustrations, 13.5 × 20 cms. New York, E. P. Dutton & Company, 1937. Price $1.50.

Here is a book, written by a recognized authority in navigation, that contains all of the information in the U. S. Government publications necessary to obtain a certificate from the U. S. Local Inspectors, Steamboat Inspection Service as Able Bodied Seaman or Certified Lifeboat Man. It treats on the mariner's compass; international rules of the road; steering orders; the log; lead line sounding machine and signals to engine room; knots and splices; lifeboats; life rafts, etc.; fire precautions and gas masks. It is a text and reference book and presents the subject in a matter-of-fact impressive manner that should be very helpful to anyone desiring information on the subject.

R. H. OPPERMANN.

THERMODYNAMIC THEORY OF AFFINITY, A BOOK OF PRINCIPLES, by Th. De Donder, and Pierre Van Rysselberghe. 142 pages, 16.5 × 25 cms. Stanford University, Stanford University Press, 1936. Price $3.00.

This is the first of what is intended to be a two volume set of books on this subject covering principles, applications and numerical examples. This first volume is devoted to principles. It is a study of the physical-chemical systems which are in thermal and mechanical equilibrium but not necessarily in chemical equilibrium.

At the very start chemical transformations of closed systems is discussed,

which is followed by the first and second laws of thermodynamics and the consequences of the two laws. The definition and hypothesis of the affinity A is next introduced and there is given a general study of open and closed systems. The properties of affinity are systematically studied: relations between affinity and chemical potentials of Gibbs, fundamental properties of these potentials, and total variation of affinity. There is a calculation of average heat of reaction and average affinity together with a detailed study of the total differential of affinity in closed systems. These results are used later for the study of transformations at constant affinity and in the states of stable equilibrium. The next subject discussed is virtual displacements in heterogeneous systems and the phase rule. Perfect gases are studied in detail. Expounded in an explicit manner is the calculation of thermodynamic potentials, the affinity and the chemical potentials of a mixture of perfect gases.

In order to compare real systems with ideal systems there is introduced the activity coefficients, the activities and fugacities. The affinity then can be written of a real system under a form very similar to that of a mixture of perfect gases. In the latter part of the book a detailed study is made on the passage of one constituent from one phase to another and the chemical reactions in a homogeneous medium. The thermodynamic properties of electrochemical systems are established and a definition is given of the power of overvoltage in irreversible electrochemical transformations.

The method, the principles of which are expounded in this work has already been successfully applied in various fields, it is stated. Necessarily, the presentation of this subject is largely by the use of formulae and their derivation, therefore it should appeal especially to the more advanced students.

R. H. OPPERMANN.

RADIO FIELD SERVICE DATA, by Alfred A. Ghirardi, E.E. Second revised edition, variously paged, illustrations, 17 × 22 cms. New York, Radio & Technical Publishing Company, 1936. Price $2.50.

This is the second edition of this reference work which has been prepared to supplement a textbook by the same author entitled "Modern Radio Servicing." It is a conveniently sized loose leaf book that can be carried to and used right on the service-man's job. Practically every section in this new edition has been improved in some manner and it is now possible to keep it up to date by a regular periodic supplement sheet service. Among the additions to this book are: intermediate peak frequency listings for sets covering 5200 models representing the products of 154 receiver manufacturers, a cross index of the model numbers of American RCA-Victor with the corresponding American G.E., Whs'e. and Graybar receivers, receiver case history of over 1500 models, and many time-saving service hints.

Radio service men will do well by acquainting themselves with this book.

R. H. OPPERMANN.

PREPARATION OF SCIENTIFIC AND TECHNICAL PAPERS, by Sam F. Trelease and Emma Sarepta Yule. 125 pages, 23 × 29 cms. Baltimore, The Williams and Wilkins Company, 1936. Price $1.50.

There are today a large number of scientific and technical men who are not well versed in the preparation and presentation of papers on a subject with which

they are intimately familiar. This is quite evident to anyone who goes through the literature. It can often be measured in the difficulty in grasping what the author has to say or in the amount of interest created. Undoubtedly, if a broad movement were undertaken by all writers to produce clearer and more interesting work, scientific and technical literature would benefit greatly.

This little handbook is written for senior and graduate students particularly, but it can also be used with profit by many practicing engineers and scientists both as a text as well as a reference. It covers the subject rather completely starting with the first steps in treating scientific data, putting ideas on paper, plan and order of topics. Then there are general suggestions on subject matter and arrangement, outlines for various compositions and how to make the article interesting. The reader is taken through treatments on the typewritten copy, preparation of manuscripts for the printer, kinds of type, preparation of table of contents, proofreading, etc.

There is a bibliography of other works on this subject at the end of the book, together with a subject index for convenient reference. The method of presentation is that of a handbook—brief and to-the-point.

R. H. OPPERMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 575. Interference of Wing and Fuselage from Tests of 28 Combinations in the N.A.C.A. Variable-Density Tunnel, by Albert Sherman. 8 pages, tables, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

Tests of 28 wing-fuselage combinations were made in the variable-density wind tunnel as a part of the wing-fuselage interference program being conducted therein and in addition to the 209 combinations previously reported in N.A.C.A. Report No. 540. These tests practically complete the study of combinations with a rectangular fuselage and continue the study of combinations with a round fuselage and a tapered wing.

Report No. 579. A Study of the Two-Control Operation of an Airplane, by Robert T. Jones. 16 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

The two-control operation of a conventional airplane is treated by means of the theory of disturbed motions. The consequences of this method of control are studied with regard to the stability of the airplane in its unconstrained components of motion and the movements set up during turn maneuvers.

It is found that the motion of a conventional airplane is more stable when an arbitrary kinematic constraint is imposed in banking than when such constraint is imposed in yawing. Several hypothetical assumptions of piloting procedure, each of which is considered to represent a component of the actual procedure, are studied. Different means of two-control operation are also discussed and it is concluded that a reliable rolling-moment control that does not give the usual adverse secondary yawing moment should be most satisfactory. Several special modifications intended to make the airplane more suitable for two-control operation are also discussed, and it is found that relatively great weathercock stability (N_v) would be desirable.

Report No. 581. Measurements of Intensity and Scale of Wind-Tunnel Turbulence and Their Relation to the Critical Reynolds Number of Spheres, by Hugh L. Dryden, G. B. Schubauer, W. C. Mock, Jr., and H. K. Skramstad. 32 pages, illustrations, tables, 23 × 29 cms. Washington, Superintendent of Documents, 1937. Price fifteen cents.

The investigation of wind-tunnel turbulence, conducted at the National Bureau of Standards with the coöperation and financial assistance of the National Advisory Committee for Aeronautics, has been extended to include a new variable, namely, the scale of the turbulence. This new variable has been studied together with the intensity of the turbulence, and the effect of both on the critical Reynolds Number of spheres has been investigated.

By the use of a modification of the usual hot-wire apparatus incorporating two hot wires suitably connected and mounted so that the cross-stream distance between them may be varied, it has been found possible to determine the correlation between the speed fluctuations existing at the two wires.

Report No. 582. A Theory for Primary Failure of Straight Centrally Loaded Columns, by Eugene E. Lundquist and Claude M. Fligg. 27 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1937. Price fifteen cents.

The primary failure of straight centrally loaded columns is defined as any type of failure in which the cross sections are translated, rotated, or translated and rotated but not distorted in their own planes. In the derivation of the general equation for the critical stress, the cross sections are assumed to rotate about any axis parallel to the column. When the location of the axis of rotation varies from zero to infinity in every direction, all combinations of translation and rotation of the column cross section are obtained.

For illustration, the theory is applied to a column of I section. The conclusions, however, are generalized to include any column with a cross section symmetrical about its principal axes. It is shown that, for such columns, the theories for bending failure and twisting failure are special cases of this general theory and that primary failure will occur by bending about the axis of minimum moment of inertia or by twisting about the centroid, depending upon which gives the lower critical stress.

It is shown how the effective width of skin that may be considered to act with the column and carry the same stress as the column alters the section properties of the column and how the bending stiffness of the skin resists twisting of the column and raises the critical stress. Finally, the effective moduli that apply when the column is stressed above the proportional limit are discussed.

Report No. 584. Strength of Welded Aircraft Joints, by W. C. Brueggeman. 32 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1937. Price fifteen cents.

The work described in N.A.C.A. Technical Report No. 348 showed that the insertion of gusset plates was the most satisfactory way of strengthening a joint. The additional tests of the present series show that joints of this type could be improved by cutting out the portion of the plate between the intersecting tubes.

T and lattice joints in thin-walled tubing 1½ by 0.020 inch have somewhat lower strengths than joints in tubing of greater wall thickness because of failure

by local buckling. In welding the thin-walled tubing, the recently developed "carburizing flux" process was found to be the only method capable of producing joints free from cracks. The "magnetic powder" inspection was used to detect cracks in the joints and flaws in the tubing.

The strengths of chromium-molybdenum T, lattice, and butt joints were materially increased by heat treatment. Butt joints in chromium-molybdenum sheet and tubing welded with low-carbon and chromium-molybdenum welding rod and those welded by the "carburizing flux" process had about the same strength in the "as welded" condition. The chromium-molybdenum and carburizing flux welds were the strongest after heat treatment.

PUBLICATIONS RECEIVED.

The Chemistry of Natural Products Related to Phenanthrene, by L. F. Fieser. 456 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corp. 1937. Price $7.00.

Matthew Boulton, by H. W. Dickinson. 218 pages, plates, 16 × 25 cms. Cambridge, University Press, 1937. Price $4.50.

Theorie der Wechselstrommaschinen in Vektorieller Darstellung, von Dr. Waldemar Michael. 272 pages, illustrations, 16 × 25 cms. Leipzig und Berlin, B. G. Teubner, 1937. Price 16.50 marks.

Elementare Physik, von Arthur Haas. 204 pages, illustrations, 14 × 21 cms. Wien, Julius Springer, 1937. Price 4.80 marks.

Generatrices et Moteurs a courant continu, par Edouard Roth et Joseph Bardin. 216 pages, illustrations, 11 × 17 cms. Paris, Armand Colin, 1937. Price 13 francs.

Cumulative Index, Journal of the Optical Society of America, vols. 1–25, 1917–1935. New York, Optical Society of America. Price $2.00.

U. S. Department of Agriculture. Daily River Stages at River Gage Stations on the Principal Rivers of the United States, vol. 33, for the year 1935. 162 pages, 23 × 29 cms. Washington, Government Printing Office, 1937. Price thirty-five cents.

Bell Telephone Laboratories, Monographs: B-968, The Surface Wave in Radio Propagation Over Plane Earth, by Charles R. Burrows, 11 pages, illustrations. B-970, Currents and Potentials Along Leaky Ground-Return Conductors, by E. D. Sunde, 21 pages, tables. B-972, The Distribution of Relaxation Times in Typical Dielectrics, by William A. Yager, 42 pages, tables. B-974, Analysis by Internal Electrolysis—I, by Beverly L. Clarke, L. A. Wooten and C. L. Luke, 9 pages, tables. B-975, Some Uses of the Torque Magnetometer, by H. J. Williams, 13 pages, diagrams. B-976, The Evolution of the Crystal Wave Filter, by Oliver E. Buckley, 17 pages, diagrams. B-980, Radio Propagation Over Plane Earth—Field Strength Curves, by Charles R. Burrows, 31 pages, diagrams. B-983, The Wave Function of a Radiating Dipole at the Earth's Surface, by S. O. Rice, 9 pages, diagrams. B-985, A Study of Long Chain Organic Compounds by Electron Diffraction, by K. H. Storks and L. H. Germer, 11 pages illustrations. 9 pamphlets, 15.5 × 23 cms. New York, Bell Laboratories, 1937.

National Advisory Committee for Aeronautics, Technical Notes: No. 595, Bending Tests of Circular Cylinders of Corrugated Aluminum-Alloy Sheet, by Alfred S. Niles, John C. Buckwalter and Warren D. Reed, 29 pages, illustrations, tables. No. 596, Full-Scale Wind-Tunnel and Flight Tests of a Fairchild 22 Airplane Equipped with a Zap Flap and Zap Ailerons, by C. H. Dearborn and H. A. Soule, 17 pages, diagrams. No. 597, Notes on the Calculation of the Minimum Horizontal Tail Surface for Airplanes Equipped with Wing Flaps, by Hartley A. Soule, 19 pages, diagrams. 3 pamphlets, 20 × 26.5 cms. Washington, Committee, 1937.

V.
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CURRENT TOPICS.

Aviation Authority Predicts Increased Air Safety.—S. M. FAIRCHILD, president of the Fairchild Aviation Corporation, states that as a result of several years' testing there is now in successful production a special airline radio compass. The universal adoption of radio compasses used in connection with improved radio range stations would be the first step in the ultimate control of air traffic which would at all times make known to the airline dispatcher, the position and altitude of every transport.

R. H. O.

Television.—LENOX R. LOHR, President of the National Broadcasting Co., recently announced conduction of the first tests of high definition television using the new standards which have been recommended by the radio industry to the Federal Communications Commission. Images scanned by the RCA Iconoscope, the pick-up tube, at the rate of 441 lines per frame have been transmitted from the NBC experimental station in the Empire State Tower and received in the homes of RCA-NBC engineers. Mr. Lohr stated that the development of television service promises to be orderly and evolutionary in character and is a tribute to the radio industry. "The public may purchase present-day radio receiving sets with confidence as to their continuing serviceability. Television receiving sets cannot precede a television program service of satisfactory quality, which will be available at the beginning only in sharply restricted metropolitan areas following the eventual solution of technical, economic and program problems."

R. H. O.

New "Synchrograph."—(*General Electric Review*, Vol. 40, No. 2.) This is a device by means of which it is possible to synchronize the quick wink of the camera eye with the lightning-like flash when taking pictures using Photoflash lamps. With it the occurrence of the light flash can be accurately controlled with respect to the brief instant the camera shutter is open. This new device is housed in a horizontal metal drum, approximately five inches long and four inches in diameter. It does its seeing in terms of split seconds. When properly hooked up between camera and a Photoflash lamp, accurate settings can be made which will cause the peak of the brief

light flash to occur while the shutter is open for its twinkling of 1/100 to 1/200 of a second.

R. H. O.

Oil-Burning Hot Water Heater.—The American Radiator Co. has developed an oil-burning domestic hot water heater, complete in one unit with dome type heater, gravity oil burner, oil storage tank and controls. The heater will operate automatically or manually on low-priced range oil or distillate. An aluminum painted dome type heater has a cast iron water heating section, with a steel combustion chamber, insulated with rock wool. A special steel baffle in the top of the heater is designed to promote efficient operation by keeping the hot gases longer in the heater. The burner, with burner shells of non-corrosive, stainless steel, has no moving parts to get out of order. The pilot and main burner assemblies rest on an iron plate bolted to the heater. The oil storage tank has a capacity of eight gallons. The capacity rating of the heater is set at forty gallons and a hot water storage tank of 40 to 60 gallon size is recommended with the heater. Tested at 315 pounds hydrostatic pressure, the heater has a guaranteed working pressure of 125 pounds.

R. H. O.

Unique Air Conditioning System Serves New Industrial Building.—R. E. HATTIS (*Heating, Piping and Air Conditioning*, Vol. 9, No. 2). A windowless, completely air-conditioned building to house the research laboratories and offices of the National Aluminate Corporation near Chicago is under construction and is scheduled for occupancy shortly. The air conditioning system is of novel design, incorporating provisions for heating and cooling the various offices and laboratories independently of each other; because of the windowless construction and the resulting high heat loads due to the lighting, and also because the absence of windows and the insulation of the building reduces heat losses in winter, it is necessary to cool some of the interior rooms when others require heating. Individual branch ducts therefore supply the 63 air-conditioned spaces, and each duct has a cooling coil and a heating coil, the first supplied with cold well water and the second with hot water from a heat exchanger, water flow to the coils being under thermostatic control. There is probably more sheet metal duct work per cubic foot of building volume in this building than in any other structure serving a comparable purpose.

R. H. O.

New Shatter-Proof Glass.—The German Correspondent of *Chemical and Metallurgical Engineering* reports in the March 1937 number of the publication that shatter-proof glass with an organic instead of silicate base is being manufactured successfully by Roehm and Haas, Darmstadt. The new organic so-called "Plexiglass," based on polymerized methyl ester and abandoning the silicate foundation, promises new uses. The esters of methacrylacid are colorless liquids, which through polymerization can be made to harden into bubble-free transparent glass in any desired thickness up to two inches. "Plexiglass" is impervious to air and rain and acids, although certain organic material, acetic esters, benzol, chloroform and alcohol dissolve it. An interesting use of the material has been in the construction of models of blood vessels of human beings and animals by filling the vessels with a special solution of "Plexiglass," marketed under the trade name of "Plastoid," which polymerizes when heated to 50 to 60 deg. C. and retains the exact form of the original model, which is later dissolved and removed. The physical and chemical properties of "Plexiglass" make it suitable for use in airplanes and automobiles. Its specific weight is only 1.18 compared with silicate glass with 2.6. Tests with $\frac{1}{8}$ to $\frac{1}{4}$ inch thicknesses of organic glass and regular glass show that "Plexiglass" can stand 8 to 10 times the blows of silicate glass before breaking. When it does crack, it does not splinter but breaks into a few large pieces whose edges are not sharp. The new glass, although not quite as hard as silicate glass, may be used for optical purposes and does not become yellow and is not easily scratched. An additional advantage is that it may be tooled like wood and metal; it can be cut, carved, etched, engraved, turned, ground, and polished, and two pieces can even be welded together without leaving a seam.

R. H. O.

Exterior Walls of Concrete House Completed in One Day.—(*Engineering News Record*, Vol. 118, No. 11.) Possibilities of accelerating concrete house construction through the use of the vacuum process for removing excess water, thus permitting the prompt removal of forms, were demonstrated recently at Bethesda, Maryland, when the exterior walls for a 27 × 37 ft. bungalow consisting of two 3 in. slabs separated by a 6 in. air space, were completely poured, the forms removed and the exterior finish coat applied in one working day. The possibility of using building paper as a form material and of applying a monolithic stucco finish to concrete walls were important corollaries of the demonstration.

The construction process involved connecting pumps to the wall forms and subjecting the fresh concrete to a vacuum so that the atmospheric pressure against the forms forced out the excess water. When the forms were stripped the green concrete thus revealed was firm and compact, with ample strength to retain its shape, even in the vertical slabs. Special form linings of cloth and panel seals of thin rubber prevent the loss of any appreciable amount of cement from the mix.

R. H. O.

Balance.—(*General Electric Review*, Vol. 40, No. 3.) While there has been equipment available to facilitate balancing small rotating machines, until comparatively recently the dynamic balancing of large rotating machines was accomplished by a slow and costly process—largely one of trial and error involving the application of various combinations of weights to the rotor. E. L. Thearle of The General Electric Research Laboratory states that a study of this problem has resulted in the development of a simple portable apparatus. It may be carried into the field and applied to any machine, and it determines the magnitudes and positions of the correct balance weights. The vibration of the machine actuates two small electrodynamic generators. Their output is, therefore, characteristic of the vibration. A meter and a mechanical rectifier analyze this output and indicate directly the phase angle and amplitude of the vibration. A first run of the machine determines the vibrations which it is desired to annul. The second and third runs, with trial weights on the rotor, determine the susceptibility of the machine to balance weights. Then a simple calculation determines the amount and position of the correct weights which will annul the original vibrations. With this apparatus, large machines may be balanced by a direct, scientific method, and in a fraction of the time required by the older procedure. This balancing equipment, which already is being used in certain divisions of the General Electric Company, should make possible further economies in the manufacture of rotating machines and work toward a more uniform and more satisfactory product. At present, this development is not being commercialized outside the Company.

R. H. O.

Automatic Radio Alarm.—According to information from the Radio Corporation of America, there has just been made available to American ship owners a new radio device for the protection of life at sea. The device is known as an automatic radio alarm, and

is intended for shipboard service in "standing watch" for emergency calls from other vessels at all times when the radio operator may be off duty, as on cargo vessels of 5,500 gross tons or over employing only one radio operator. Charles J. Pannill, President of the Radiomarine Corp. of America said that the new alarm had received the approval of the Federal Communications Commission after a rigid, sixty-day test, both in the Bureau of Standards laboratories and in the Sandy Hook stations of the U. S. Coast Guard. When connected, the device is set for reception on the 600 meter distress call wave, and adjusted so as to recognize a distress signal. When such a signal is received it rings bells and turns on warning lights, calling the attention of the operator. In addition to this the same alarms are automatically operated should the device itself become defective.

R. H. O.

Rogue's Gallery.—In *Electrical Contracting* for March 1937 there is an interesting exhibit consisting of photographs of horrible examples of avoidable electrical hazards taken from the files of the publication. One shows a spray booth where illumination is provided by a bare lamp on a drop cord. Light is directed by a misfit reflector and a piece of paper. The reflector is tied to the socket and allowed to contact the metal frame. It is pointed out that one short circuit will cause an explosion. Another picture was taken in a food processing plant. It shows light switches and fuse blocks on a 220 volt circuit, mounted in an inclosing case. The door, however, was allowed to remain open and there is a considerable collection of dust in the case and on "live" parts. There are six photos, each one of which serves to call attention to dangers that exist through negligence or ignorance. These and similar hazards may present themselves in any industrial plant unless constant and strict observance is maintained.

R. H. O.

Largest Spiral-Guided Gas Holder Being Erected.—(*Gas Age Record and Natural Gas*, Vol. 79, No. 6.) This is being erected at Wincobank, Sheffield, England. In circumference this gas holder may be likened to a speedway track. Its total weight, when completed, will be 3495 long tons; and the total capacity of four lifts will be 8,052,226 cu. ft. The number of rivets in the tank itself will be 120,000, while the four lifts will have 868,700. The largest rivets used are 1 9/16 in. in diameter by 6 7/8 in. long.

R. H. O.

International Vocabulary.—The International Electrotechnical Commission plans early publication of the first edition of its international "Vocabulary." This work, undertaken soon after the St. Louis Electrical Congress in 1904, contains some 2,000 scientific and industrial terms used in the various branches of electrotechnics. The committee of experts who compiled this work is composed of delegates from many countries. The whole work is divided into 14 sections, the first of which covers fundamental and general definitions. The others more specifically deal with: machines and transformers; switchgear and control gear; apparatus for scientific and industrial measurements; generation, transmission, distribution; electrical traction; power applications; thermic applications; lighting; electro-chemistry; telegraphy; telephony; radiology; electrobiology. Definitions appear in both English and French, and a translation of terms alone is given in German, Italian, Spanish, and Esperanto.

R. H. O.

Efficiency of Motor Lubricants Determined by X-Ray Method.—(*Oil and Gas Journal*, Vol. 35, No. 44.) Successful application of an X-ray method in testing motor lubricants for their efficiency in protecting metals from injurious surface wear has been announced by the Continental Oil Co. Differing radically from any previous test, the process provides that metal first be subjected to a powerful X-ray beam. Much as sunlight is diffracted by a pane of glass, the beam is diffracted by the metal and a picture taken of the pattern created by the diffraction. Then the metal is lubricated and run under a constant load for a given time, following which the metal is again subjected to the X-ray beam. Differences in the pictures of the diffraction pattern taken before and after the metal has been worked reveal the efficiency of the lubricant, since they reveal the degree change which has taken place within the internal structure of the metal. Obviously the lubricant which permits the least such change is the most efficient lubricant. In the past, scientists, seeking to classify lubricants as to efficiency, have tested the oil for its chemical nature, viscosity, color and similar qualities. However, many authorities today hold the opinion that modern engines operating under terrific load and stress have rendered all such tests obsolete; and that the contemporary scientist can hope accurately to determine the degree of protection from wear which a lubricant affords only by tests of the metal before and after it has been worked with the lubricant in question.

R. H. O.